FINAL REPORT

INVESTIGATION AND MITIGATION OF HAZARDOUS WASTE SITES LEVEL-OF-EFFORT (LOE) CONTRACT MOBILIZATION ORDER NO. 531-01

EMD CHEMICALS, INC. (f.k.a. EM SCIENCE) FEASIBILITY STUDY

Prepared for:

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1.0 INTRODUCTION

As part of a Remedial Investigation/Feasibility Study (RI/FS), the Ohio Environmental Protection Agency (Ohio EPA) has prepared this streamlined Feasibility Study (FS) report for what is known as the EM Science site (Site) in Cincinnati, Ohio. EM Science was a division of EM Industries, Inc. Hawthorne, New York. EM Science has changed its name to EMD Chemicals Inc. For the purposes of this document, the Site continues to be referenced as the EM Science site. The Site is a chemical manufacturing facility that provides chemicals to laboratories and other commercial and industrial manufacturers. This streamlined FS identifies and evaluates a range of remedial alternatives to address contamination at the Site, which was evaluated during the Remedial Investigation (RI).

On December 24, 1992, EM Science entered into an Administrative Order on Consent (AOC) with the Ohio EPA to complete a RI/FS at the Site. Section 1.3.3 describes activities at the Site prior to the AOC. The RI/FS required activities were presented in EM Science's *Work Plan for Remedial Investigation/Feasibility Study, EM Science Site, Cincinnati, Ohio* (RI/FS Work Plan) dated November 19, 1993. The purpose of the RI/FS is to characterize the nature and extent of risks posed by soil and perched ground water contamination beneath the Site, and to evaluate potential remedial alternatives for mitigating the risks.

EM Science conducted RI activities at the Site between February 1994 and October 1996. The results of the RI are presented in the approved *Remedial Investigation Report for the EM Science Site, Cincinnati, Ohio* (RI Report), dated October 26, 1996. FS activities were conducted between November 1996 and January 2000. EM Science submitted a Draft FS Report to Ohio EPA on May 27, 1999. Ohio EPA noted deficiencies and violations of the Director's Findings and Orders (F&Os) presented in the AOC. EM Science submitted a Revised Draft FS Report to Ohio EPA, dated January 21, 2000. Ohio EPA again noted deficiencies and violations with the F&Os. Pursuant to Section XIV of the F&Os, Ohio EPA opted to complete the EM Science draft FS Report. The history of this decision is summarized in Ohio EPA's letter to EM Science dated December 8, 2000. Ohio EPA prepared a Streamlined FS report ("SFS") in November 2001. In response to comments from EM Science, an Addendum to the Streamlined FS was prepared in January 2002. Additional comments and discussion with EM Science have been incorporated into the current Streamlined FS. This SFS includes sections of the original (January 2000) EM Science's draft FS Report that were accepted by Ohio EPA. Original text from the EM Science draft FS is highlighted in Section 1 of this SFS report. Sections that were added or revised by Ohio EPA in order to comply with appropriate guidance and regulations are shown in non-highlighted text.

This SFS report was prepared in a manner consistent with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988) and with 40 CFR Part 300, the National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule (NCP). The following sections describe the purpose and scope of the SFS report and the organization of the report, and provide a summary of the site background and history.

1.1 PURPOSE AND SCOPE

This report evaluates possible methods for removing, treating, or containing contaminated soil/fill and perched ground water beneath the Site such that potential risks to human health and the environment are eliminated or minimized. The requirements of the FS are outlined in Section 6.0 of the RI/FS Work Plan, and TASK 8 (Development and Screening of Remedial Alternatives), TASK 9 (Treatability Study), and TASK 10 (Detailed Analysis of Remedial Alternatives) of the Ohio EPA's Generic Statement of Work Remedial Investigation/Feasibility Study (SOW), which was attached to the AOC. This report was preceded by EM Science's October 3, 1997 Remedial Action Objectives Technical Memorandum No. 10, EM Science RI/FS, Cincinnati, Ohio (RAO TM 10), and July 6, 1998, Alternative Arrays Report Technical Memorandum No. 14, EM Science RI/FS, Cincinnati, Ohio (AA Report TM 14). As required by the SOW, these were submitted to the Ohio EPA as interim documents and portions of the FS Report.

Consistent with the RI/FS Work Plan, SOW, NCP, and RI/FS Guidance, this report examines an appropriate range of RAs. The FS primarily relies upon data presented in the RI Report for developing and analyzing an appropriate range of remedial action alternatives. The NCP requires that nine criteria be considered during development of the remedial alternatives. These criteria include long- and short-term effectiveness, implementability, overall protection of human health and the environment, cost, adherence to applicable or relevant and appropriate requirements (ARAR), reduction in toxicity, mobility and volume through treatment, and state and public acceptance. The first seven criteria (Seven Evaluation Criteria) are used to evaluate each RA individually and in comparison to all other RAs. The Ohio EPA will use this information during selection of a preferred alternative. Because this SFS is developed by Ohio EPA, "state acceptance" criteria will not be specifically considered in this SFS.

The overall intent of this FS Report is to use available RI data, existing remedial engineering literature, treatability study results, and U.S. EPA guidance documents and technical reports to make supportable decisions during the development and detailed and comparative analysis of the RAs. Consistent with the RI/FS Guidance, FS cost estimates fall within a range of +50 percent to –30 percent. To provide a uniform basis for cost comparisons, RA cost estimates are presented in present worth costs. Present worth costs reflect the quantity of money, which must be placed in a bank today at a set interest rate, termed the discount rate, to pay for the remedial action over the life of the project.

During the FS, additional data was acquired from specific areas of the site to further define certain site characteristics documented in the RI Report, and to provide sufficient data to allow in-situ treatment technologies and options to be fully evaluated to support the development of RAs. These additional data needs involved the drilling of additional soil borings, installation of additional monitoring wells, the completion of a pumping test in the Upper Sand Unit, and the performance of three on-Site treatability studies. Relevant Technical Memorandums (TM) and Technical Amendments (TA) that were prepared and submitted to the Ohio EPA for review and approval during the FS are listed on Table 1-1. The purpose of these interim documents was to summarize the tasks and results associated with the work that was performed, and to reduce costs and performance uncertainties for treatment process options so that appropriate RAs could be developed.

The remedial technologies tested by The Payne Firm (a consultant for EM Science) and selected sub-contractors were soil vapor extraction (SVE), dual phase extraction (DPE), and hydraulic fracturing. Each is an in-situ technique, intended respectively to recover VOC vapors, recover VOC vapors and ground water, or to improve the permeability of Site soils. The proposed scope of the combined SVE and DPE treatability study was presented to the Ohio EPA in The Payne Firm's Final Work Plan, Treatability Study, Phase II, submitted April 22, 1998 and modified on May 12, 1998, which was approved in a letter from the Ohio EPA dated May 15, 1998. The results of the SVE and DPE treatability studies were submitted to the Ohio EPA in Technical Memorandum No. 15, Final Results, Treatability Study-Phase II on September 29, 1998 and approved in a letter from the Ohio EPA dated November 4, 1998. The tasks for the hydraulic fracturing treatability study were presented in the Work Plan, Treatability Study Phase III, Fracture-Enhanced Soil Vapor Extraction, submitted to the Ohio EPA on October 1, 1998, approved by the Ohio EPA in a letter dated October 23, 1998. Data collected during the hydraulic fracturing feasibility study and conclusions drawn were presented in The Payne Firm's Technical Memorandum No. 16, Results, Fracture-Enhanced Soil Vapor Extraction, Treatability Study Phase III, which was submitted to the Ohio EPA on January 14, 1999 and approved by the Ohio EPA in a letter dated February 8, 1999. In addition, TM-12 summarized the feasibility of ground water pumping from the Upper Sand Unit to reduce contaminant mass; and, TM-13 summarized the results of additional soil borings that were drilled at the Mouth of the West Ravine to further define the geology and distribution of VOCs in the vicinity of a proposed surface water collection sump.

1.2 REPORT ORGANIZATION

This report is organized into seven Sections:

Section 1.0 Introduction - The remainder of this section presents a Site description, a summary of the history of the EM Science Site, and a general summary of the RI Report. Additional details regarding these issues can be located in the RI/FS Work Plan and the RI Report, which are available in the Ohio EPA's files.

Section 2.0 Remedial Action Objectives – This section identifies remedial action objectives (RAOs) and preliminary remediation goals (PRGs) for contaminated media at the Site. In addition, this section describes applicable or relevant and appropriate requirements (ARARs) as required by the NCP that are pertinent to the alternatives discussed in this FS.

Section 3.0 Screening and Identification of Technologies and Process Options - The results of identifying and screening remedial technologies and process options for soil/fill and perched ground water are presented in this section.

Section 4.0 Development of Remedial Action Alternatives - This section explains the development and assembly of alternatives using the screening information presented in Section 3.0, and presents a detailed description of the alternatives being considered.

Section 5.0 Detailed Analysis of Remedial Action Alternatives - The results of a detailed evaluation of the alternatives assembled in Section 4.0, using seven of the eight pertinent NCP evaluation criteria, is presented in this section.

Section 6.0 Comparison of Remedial Action Alternatives – This section compares the ability of each of the alternatives to satisfy the seven NCP evaluation criteria.

Section 7.0 References

1.3 SITE BACKGROUND

This section is a general overview of the chemical, physical, operational, and regulatory aspects of the EM Science Site.

1.3.1 Site Description

EM Science is a Division of EM Industries, Inc., Hawthorne, New York. The EM Science property is comprised of nine acres in the Northern 1/2, Northwest 1/4, Section 28, Fractional Range 2, Township 4, Miami Purchase, Cities of Norwood and Cincinnati, Hamilton County, Ohio with latitude 39° 9' 55" and longitude 84° 26' 10" (see Figure 1-1). The EM Science facility is located northwest of the intersection of Interstate 71 (I-71) and State Route 562 (also referred to as S.R. 562 or "Norwood Lateral"). The Site is bounded by Highland Avenue on the north, the Norwood Lateral on the south, Shepherd Chemical Company on the west, and a Norfolk Southern railroad embankment on the east (see Figure 1-2). The western portion of the property lies within the City of Norwood and occupies approximately 6.62 acres. The eastern portion of the EM Science property is located within the City of Cincinnati and occupies approximately 2.38 acres. Most of the plant operations through the years have been conducted on the Norwood portion of the property. The EM Science property is almost entirely paved with concrete or asphalt except for some gravel covered areas in the central and southern portions of the facility, and a grassy area east of Building 14.

The EM Science property is located in a mixed commercial/industrial/residential setting. The areas west and north of the facility consist predominantly of industrial manufacturing, warehousing, chemical production, and service companies. A few residential houses are located northwest of the EM Science property along Highland Avenue. Immediately beyond the Norfolk Southern railroad embankment, the topography east of the facility steeply slopes to a lower parking lot belonging to Duramed Pharmaceutical, Inc. South of the EM Science property, the Norwood Lateral and associated on and off-ramps separate the facility from I-71 and a residential area located 500 feet southwest of the property. The original topography of the property included two ravines associated with the Duck Creek drainage system (referred to as the former East Ravine and former West Ravine in the RI/FS Work Plan). The geology and hydrogeology, and contamination associated with these ravines are discussed in Sections 1.3.2 and 1.3.9, respectively. Duck Creek is situated in a concrete channel located approximately 600 feet southeast of the EM Science facility. The East and West Ravines have been filled to present grade which slopes from an elevation of 614 feet above mean sea level (MSL) on the western perimeter of the property to approximately 598 feet MSL along the eastern property boundary. South of the EM Science property, the surface slopes abruptly (a 2:1 engineered slope developed during the Construction of the Norwood Lateral in the late 1960s) from an elevation of approximately 606 feet MSL to 580 feet MSL along the Norwood Lateral.

1.3.2 Geology and Hydrogeology

The Site Geological Model (SGM) consists of three main hydrostratigraphic systems: a Perched Ground Water System, a Confining System, and a Confined Aquifer System (see Figure 1-3). The Confined Aquifer System (i.e., Norwood Trough Aquifer) is separated from the Perched Ground Water System by approximately 100 feet of non-saturated deposits associated with the Confining System. The extensive amount of geological and geotechnical data used to develop the SGM demonstrated that there are limited pathways for horizontal or vertical contaminant migration beneath the Site. Potential contaminant migration horizontally is restricted to discontinuous perched ground water zones within the Perched Ground Water System. Vertically, migration is restricted by silt and clay deposits associated with the lower portion of the Perched Ground Water System (i.e., Lacustrine and Lower Clay Units), and the units within the Confining System which include: the 10 to 30 feet thick Lower Till Unit which is present beneath the entire Site; and, underlying the Lower Till Unit, the 90 to 100 feet thick unsaturated, partially cemented, silt, sand, and gravel deposits situated below the upper portion of the Norwood Trough Sand and Gravel Unit (i.e., Upper Non-Saturated Zone).

The hydrogeology varies considerably within the predominantly silt and clay-rich Perched Ground Water System. Ground water is restricted to discontinuous sand seams and lenses, and to the backfill of storm sewers. Perched ground water is more prevalent beneath the central and eastern portions of the Site where coarser seams and lenses exist. The majority of the monitoring wells screened within the Perched Ground Water System are low yielding and slow to recharge.

The low permeability clays and silts, which dominate the Perched Ground Water System, behave as an aquitard that can store perched ground water but transmit it slowly from one porous saturated zone to another. Flow directions in the Perched Ground Water System are artificially controlled by the French Drain and P6A (when pumping). No perched ground water exists in the Confining System. The Norwood Trough Aquifer, situated at a depth of 175 feet below the facility, was demonstrated to be under confined conditions beneath the Site.

A summary of the relevant issues associated with the Site physical setting is presented below:

- The EM Science Site is situated within the Norwood Trough buried glacial valley. The bottom of the Norwood Trough lies at about 375 feet MSL, or approximately 235 feet below the Site. The bottom two-thirds of the Norwood Trough are filled with fining upward outwash sand and gravel deposits that are up to 125 feet thick; the upper one-third consists of 80 to 125 feet of glacial tills, glaciofluvial, and glaciolacustrine deposits. The Norwood trough Aquifer (NTA), a U.S. EPA designated sole source regional aquifer, exists in the basal saturated portion of the outwash sand and gravel deposits. Within a one-mile radius of the Site, ground water pumped from the NTA is used solely for industrial production purposes; no water derived from the NTA is utilized for drinking.

- The Site is located within the Little Miami River drainage basin above the 100-year flood plain. The nearest surface water body is Duck Creek located 600 feet southeast of the EM Science property. In the vicinity of the Site, Duck Creek is an ungaged stream with no measured peak flows and is predominantly confined to aboveground and belowground-engineered concrete channels. The 84-inch storm sewer at the bottom of the former East Ravine discharges into Duck Creek southeast of the facility. Besides Duck Creek, no other significant surface water bodies are located in the vicinity of the Site.

- The three hydrostratigraphic systems within the SGM are summarized below:

1. <u>Perched Ground Water System</u>

The Perched Ground Water System occurs within the upper portion of the SGM and consists of the following three sub-systems:

Vadose Zone - The Vadose Zone consists of the upper 30 to 40 feet of fill and glacial overburden including deposits of the Upper Till Unit and the fill of the former West and East Ravines. The Vadose Zone is predominantly unsaturated except for perched ground water occurring in: thin sand seams in the Upper Till Unit; the fill of the former West and East Ravines; and, the backfill of the 84-inch and 27-inch storm sewers. Monitoring wells screened in the Vadose Zone are low yielding and slow to recharge.

Fill material within the Vadose Zone has been placed across the entire property and can be divided into three main categories: 1) general surficial soil/engineering fill situated above the Upper Till Unit; 2) the fill of the former West Ravine; and, 3) the fill of the former East Ravine. The characteristics of these three fill types are extensively described in Section 3.4.1.1 of the RI Report. The latter two categories are more important to the FS process, and are described in general below:

Former West Ravine Fill - The former West Ravine is located in the central portion of the facility. The former West Ravine fill material primarily consists of a clay and silt matrix with varying amounts of sand, gravel, broken pieces of glass, larger fragments of concrete, wood and metal construction debris, wood chips, and frequent soil staining. Lesser amounts of debris are present in the upper northwestern portion of the ravine (Upper West Ravine) than in the southeastern portion (Middle West Ravine). Large slabs of concrete, logs, glass bottles, rubber car tires, metal strips, and plastic bottle caps are visible near the bottom of the fill material at the mouth of the former West Ravine (Mouth of the West Ravine). At the Mouth of the West Ravine, the fill material slopes down the steep walls of the former ravine and represents the terminus of filling activity. The Outfall which discharges water from the ravine is present at the south end of the fill. Three on-property test pits dug into the first upper 10 feet of the fill material during previous Site investigations in the late 1980s also encountered the same type of fill materials described above.

According to the RI Report, the thickness of the fill increases from the northwest to the southeast with the thickest portions occurring along the longitudinal axis of the former ravine. The fill material becomes increasingly thinner perpendicular to the ravine axis reflecting the placement of materials on the slope of the former West Ravine. Fill material is not present south of the Outfall except surficially along the walls of the former ravine. The fill of the West Ravine sits on top of the Upper Till Unit everywhere except at the southeastern one-third portion of the former ravine. As discussed in the RI Report, the channel of the former ravine progressively eroded soils from northwest to southeast. In the lower portion of the Middle West Ravine and at the Mouth of the West Ravine, the Upper Till Unit is completely eroded away and the fill material sits directly on top of the Lacustrine Unit.

Ground water flowing along the base of the West Ravine fill discharges to concrete ditches at the Outfall and at Seep-562; the conduits funnel discharged water to Sump-562. The fill in the former West Ravine is non-engineered and heterogeneous and is, therefore, conducive to the occurrence of voids and channels. Some of the discharge from the Outfall and Seep-562 may originate from perched ground water voids in the fill that are recharged by water flowing into the fill from Upper Till sand seams.

Because the majority of the facility is capped with asphalt and concrete, and EM Science maintains an active storm water management program, a very limited infiltration may contribute to a small part of the discharge at the Mouth of the West Ravine. During the RI field investigation, the baseflow discharge at the Outfall was approximately 0.5 gallons per minute (gpm). During rain events, the discharge increased to approximately 5 to 10 gpm, but then decreased back to baseflow soon after the rain event ceased. The discharge at Seep-562 was too negligible to quantify during the field investigation. Groundwater/ leachate discharged from the Outfall to Sump 562 and from Seep 562 at the Mouth of the West Ravine, which is typically pumped to the treatment facility, can bypass treatment during heavy precipitation events. This overflow discharges to a 27-inch storm sewer that flows southward from the site and joins the 84-inch storm sewer, eventually discharging to Duck Creek.

East Ravine Fill - Prior to completion of the RI, the environmental implications associated with the fill of the former East Ravine were not determined during previous Site investigations because historical review indicated that the material was primarily soil and construction material derived from off-property sources. More emphasis was placed on investigating the fill of the former West Ravine since most of the materials were derived from on-property sources. In the RI/FS Work Plan, it was determined that there was a need to confirm that East Ravine fill was not derived from, or impacted by, historical on-property operations.

The fill of the former East Ravine resembles the surficial fill encountered outside the boundaries of the former West Ravine. It consists predominantly of soft to medium dense silt and clay with minor amounts of sand, gravel, and small pieces of brick, concrete, asphalt, and wood debris. Some larger pieces of typical construction debris (e.g. plywood, drywall, plastic sheeting) were sparsely encountered in the first 15 to 20 feet of the fill at a few of the boring locations drilled during the RI. In contrast to the West Ravine fill, no widespread occurrence of broken glass, plastic caps, or soil staining was observed. Also in contrast, the thickness of the fill remains consistently between 32 and 36 feet along the northwest to southeast trending axis of the former East Ravine. This occurs because the former East Ravine was a more elongated and broadly shaped drainage ravine extending approximately 200 to 250 feet north and south of the property line before it was filled. As discussed in the RI Report, the western wall of the former East Ravine was more steep than the gently sloping eastern wall which contributed to: 1) the broadness of the ravine and the relative consistency in the thickness of fill encountered in soil borings; and, 2) the extension of fill material beyond the northern, eastern, and southeastern property boundaries.

Similar to the West Ravine, the geologic development of the East Ravine eroded away most of the Upper Till Unit and the majority of the Lacustrine Unit. North of a line that extends from borings VE402 east to VZ408 and VZ409, (see Figure 1-4), the East Ravine fill sits on top of silt and fine grained sand deposits associated with the top of the Lower Clay Unit. South of that line, the Lower Clay Unit is more silt and clay rich.

Beneath the fill of the former East Ravine, backfill materials around the 84-inch storm sewer pipe, which traverses the longitudinal axis of the ravine, contain perched ground water. Monitoring wells MW18, MW23, and MW506 are monitoring the perched ground water, which is derived from infiltration. Perched backfill ground water monitored at the eastern property boundary at MW18 and MW23 is believed to flow into the 84-inch storm sewer at Seep C, and downgradient to MW506 located approximately 225 feet southeast of the property. The ground water elevation at MW506 is approximately 4 feet lower than the elevation observed at MW23 as depicted on the Vadose Zone potentiometric maps in Appendix J of the RI Report. In addition, monitoring well MW504 monitors perched backfill ground water that flows from the vicinity of Sump-562 to the area beneath the S.R. 562 median.

2. <u>Confining System</u>

Beneath the Perched Ground Water System is a Confining System, which is situated above the Norwood Trough Aquifer (Figures 1-3). The Confining System is approximately 100 to 110 feet thick and consists of the Lower Till Unit (including the Lacustrine 3 Zone), and the unsaturated deposits of the Norwood Trough Sand and Gravel Unit (i.e., Upper Non-Saturated Zone). No saturated sand seams or pockets were observed in the numerous borings drilled into the Lower Till Unit, or in four borings drilled into the Upper Non-Saturated Zone. The Lower Till Unit is situated between 65 and 80 feet below the Site and is present beneath the entire Site. The dense, homogenous unit ranges between 12 and 31 feet thick. The hydraulic conductivity values in the Lower Till Unit typically ranged between 1 x 10^{-8} and 1 x 10^{-9} cm/s, which were the lowest values observed in the SGM. The mean moisture content for the 32 samples collected from the Confining System was approximately 11.2% indicating non-saturated conditions.

3. Confined Aquifer System

The 50 feet thick Lower Saturated Zone of the Norwood Trough Sand Gravel Unit (i.e., Norwood Trough Aquifer or Confined Aquifer System) exists beneath the Confining System. Beneath the Site, the Norwood Trough Aquifer (NTA) is under confining conditions as demonstrated by the ground water elevation test at LT338. Thick sequences of shale and limestone bedrock exist beneath the NTA. The 100 feet thick unsaturated Confining System between the bottom of the Perched Ground Water System and the top of the NTA indicate that it is very improbable that contaminants detected below the Site will migrate to the NTA.

- Potential vertical contaminant migration within the SGM is limited by the silt and clay rich nature of the Upper Till, Lacustrine, Lower Clay, and Lower Till Units. The geotechnical properties of these units have assisted in impeding the widespread vertical migration of contaminants from on-property areas of contamination. The thickness characteristics and homogeneous nature of the Lower Till Unit, in combination with the unsaturated properties of the Non-Saturated Zone of the Norwood Trough Sand and Gravel Unit, reduce the potential for contaminants to migrate beneath the Perched Ground Water System.

- Ground water flow in the Perched Ground Water System is primarily west to east beneath the property (Figure 1-3). Potential horizontal contaminant migration routes within the Perched Ground Water System are restricted to: 1) man-made conduits within the Vadose Zone; 2) the Upper Sand Unit in Perched Zone I where migrating contaminants are captured by the French Drain; and, 3) Perched Zone II deposits situated beneath the central and southern portions of the Site. The horizontal migration of contaminants beneath the central portion of the Site in Perched Zone II is restricted by pumping well P6A. Beneath the southern portion of the Site, migration is restricted by the limited hydraulic capabilities of thin, discrete, silty sand seams within the clay-rich Lacustrine Unit. In the Vadose Zone, Sump-562 captures perched ground water flowing from the Outfall and from the Seep-562. The only other routes of migration in the Vadose Zone include the backfill around the 27-inch and 84-inch storm sewers, and the seep at Sewer C in the 84-inch storm sewer. These routes are severely limited, however, by the low availability of perched ground water and the lateral extent of the sewer lines.

- A limited hydraulic gradient test at conducted P6A during the RI indicated that: 1) the potential horizontal contaminant migration route from the central portion of the facility to the eastern property boundary in Perched Zone II (in the absence of pumping at P6A) is restricted by the heterogeneity of the deposits within the Lacustrine and Lower Clay Units; and, 2) monitoring well MW23 (screened in the backfill of the 84-inch storm sewer along the eastern property boundary) is in very limited hydraulic communication with P6A. The heterogeneity of the Perched Zone II deposits restricts the ability to quantitatively determine the rate of contaminant movement from the area south of Building 10 to the eastern property boundary during non-pumping conditions at P6A.

- Population within a one-mile radius of the Site is approximately 23,000 residents. Slightly more than one-half of the one mile area is residential, and the other half being industrial or commercial property, transportation corridors, parks, or undeveloped land. No areas allowing recreational hunting or fishing are present within one mile of the Site.

1.3.3 Site History

This section describes the site ownership and development history, historical source areas, administrative history, and interim actions.

1.3.4 Site Ownership and Property Development

The EM Science property is composed of three previously existing parcels that were acquired by previous owners of the facility. The property is almost entirely paved and contains numerous production, warehousing, and office buildings along with other existing chemical manufacturing and storage structures (see Figure 1-2). During the RI and previous investigations, numerous on-property and off-property monitoring wells were constructed as shown on Figure 1-4. The construction, screen interval, and soil strata and ground water intersected by post-RI monitoring wells are also presented in Table 1-2. The filling of the former West Ravine with soil, waste materials, and other debris by previous owners of the facility occurred between 1952 and 1971. A 15-inch storm sewer was placed at the base of the West Ravine as it was progressively filled from the northwest to the southeast. The slope of the fill of the West Ravine and the terminus of the storm sewer (or Outfall) are situated within the mouth of the West Ravine, which is located at the southeastern corner of the facility. The East Ravine was filled with soil and construction debris between 1938 and the early 1970s. There is no record of chemical placement in the East Ravine. An 84-inch storm sewer constructed by EM Science exists within the former channel of the East Ravine.

1.3.5 Historical Source Areas

Areas that were potential historical chemical release locations at the EM Science facility include:

1. **Middle West Ravine** - The central and southeastern portion of the property, consisting primarily of the fill in the West Ravine and underlying soils, impacted by the release of virgin and off-specification chemicals and diluted spent oleum. Contaminated ground water discharged from the Outfall is collected by a concrete sump (Sump-562) in the West Ravine mouth. EM Science constructed Sump-562 in 1983 as an interim action.

2. **Building 10 Area** - The area immediately south of Building 10 (a former chemical distillation and production building). This area contained a process sewer line that ran from the Building 10 to the West Ravine where it discharged to the ground. Contaminants originating from the process sewer have migrated to perched ground water that is captured beneath the eastern portion of the facility by a French Drain collection system. The French Drain was constructed by EM Science in 1988 to prevent off-property contaminant migration. In 1992, EM Science constructed and began operations of an interim action gradient control well (P6A), located beneath the western edge of the former East Ravine. Its purpose is to prevent the migration of perched ground water contaminants in coarse-grained deposits beneath the French Drain to the eastern property boundary.

3. **Building 4 Area** - A trench drain discharged at the northeast and southeast corners of building 4. Approximately 40 feet farther east a chemical Tank Farm formerly existed. The former Tank Farm contained aboveground and belowground tanks that stored bulk chemicals used in previous manufacturing processes. Contaminants originating from this area of the property have migrated to a ground water seep (Seep-562) located along an engineered cut-slope west of Sump-562. This seepage is also collected by Sump-562.

4. **East Ravine and Upper West Ravine** – These areas were filled primarily with soil and small amounts of construction debris. Risk analysis performed during the RAO indicated both areas pose no unacceptable risks to human health and the environment beyond extended direct contact or inhalation of contaminated soil particles.

1.3.6 Administrative History

In 1981, the U.S. EPA and Ohio EPA analyzed leachate collected at the mouth of the West Ravine during Resource Conservation Recovery Act (RCRA) inspections of the facility. In response to this initial data collection activity, EM Science began to voluntarily assess the nature and extent of contamination at the Site. An initial "Draft RI/FS Work Plan" was submitted to the Ohio EPA in 1985 and EM Science proceeded with "voluntary RI" sampling activities focused on identifying potential contaminant source areas and off-property contaminant migration pathways. The work scopes and tasks were primarily focused on: 1) obtaining technical data to support responsible party litigation against previous owners of the facility; 2) identifying contaminant source areas where known releases occurred; 3) assessing the waste characterization and volume of contaminated materials in the West Ravine; and, 4) collecting hydrogeological and contaminant data for the implementation of interim remedial actions.

Subsequently, three "Draft RI Reports" dated November 7, 1986, November 10, 1988, and February 7, 1990, were submitted to the Ohio EPA by EM Science documenting the results of the voluntary investigations. The Ohio EPA provided comments to each of the Draft RI Reports to assist EM Science in identifying potential data gaps in its voluntary assessment. A bibliography of the applicable existing documents associated with the 1981 to 1990 investigations was presented in Section 2.3.1.0 of the RI/FS Work Plan (p. 2-27 to 2-28).

In a May 31, 1992 letter, the Ohio EPA invited EM Science to enjoin in an AOC that would "govern the management and completion of future EM Science RI/FS activities". As a result, EM Science and the Ohio EPA entered into an AOC to conduct a comprehensive RI/FS for the Site following the Ohio EPA RI/FS SOW on December 24, 1992.

Pursuant to the AOC, EM Science submitted a RI/FS Work Plan and supporting documents to the Ohio EPA, which was approved on February 28, 1994. The RI/FS Work Plan reviewed pertinent historical data associated with the Site in Sections 2.3.0 (Previous Investigations, p. 2-26 to 2-38) and 3.1.0 (Review of Existing Data, p. 3-1 to 3-14). The review of the existing data indicated that four primary data gaps were present: 1) a complete definition of the nature and extent of soil and ground water contamination at the Site; 2) a thorough hydrogeological assessment of deeper lacustrine, till, and sand and gravel deposits beneath the Site; 3) a complete quantification of the actual or potential risks to human health and the environment; and, 4) a quantitative analysis of the representativeness and usability of the existing analytical data base. Subsequently, EM Science and The Payne Firm completed the RI tasks in the RI/FS Work Plan from February 1994 to October 1996 to address these and other related minor data gaps.

1.3.7 Feasibility Study

After the RI tasks were completed in 1996, EM Science and The Payne Firm began work on an FS. EM Science submitted a Draft FS Report and a Revised Draft FS report to Ohio EPA in May 1999 and January 2000, respectively. In December 2000, the Ohio EPA notified EM Science that the agency would complete the FS in order to correct deficiencies in the report. This document is the result of that effort and includes sections of EM Science's draft FS Report (highlighted text in Section 1).

1.3.8 Interim Actions

During the voluntary investigations undertaken by EM Science prior to the 1992 AOC, four interim actions were implemented by EM Science during the 1980s and early 1990s. The interim actions consisted of a: 1) surface water collection sump; 2) storm water management program; 3) French Drain ground water collection system; and, 4) hydraulic gradient control ground water collection pump (see Figure 1-2). These actions were taken to mitigate the migration of contamination off-property identified during field activities, and thereby reduce the potential for exposure to human health and the environment.

Implementation of the interim actions required interaction with appropriate governmental or regulatory agencies before installation. Specifically, the surface water sump and small concrete trough at the Mouth of the West Ravine in the right-of-way of S.R. 562 was permitted by the Ohio Department of Transportation (ODOT). ODOT also permitted installation of a fence around the surface sump to protect human health and the environment. The MSD and Ohio EPA issued a Permit to Install (PTI) and a Permit to Operate (PTO) for the sump discharge to the MSD POTW. A PTI and PTO was also issued for discharges to MSD from the French Drain and P6A.

In accordance with the RI/FS Work Plan, an Interim Action Efficacy program was conducted during the RI to technically evaluate each of the existing interim actions. The program demonstrated that each interim action was performing at a level consistent with its original performance objectives and goals. The results were documented in The Payne Firm's Interim Action Efficacy Report (Efficacy Report), which was approved by the Ohio EPA on March 20, 1995.

Specific monitoring tasks are completed each month by EM Science to further evaluate the efficacy and reliability of two of the interim actions (Outfall surface water sump and French Drain). The results of the tasks are presented in the Monthly RI/FS Report required by TASK 11 of the SOW. Besides the four pre-RI interim actions, two additional interim actions were completed by EM Science. A fencing interim action was emplaced during the RI, and a hot spot soil delineation and removal interim action was conducted during the FS. The following paragraphs provide a brief overview of the interim actions that have been implemented at the Site.

Surface Water Sump at the Mouth of the West Ravine

EM Science constructed a concrete collection sump (Sump-562) at the mouth of the West Ravine in 1983 to intercept and capture contaminated surface water during storm events and seepage from the West Ravine fill. The objective of the ongoing sump is to accommodate flow equivalent to a 10-year, 24-hour storm event, and to prevent the release of Site-related contaminants to a storm sewer located immediately down stream of the sump. Sump-562 and associated collection ditches have been maintained, monitored, and updated by EM Science over the years with improved controls and more efficient pumps. Non-contaminated water from Sump-562 is segregated and bypassed such that an overflow of the system only occurs during severe storm events (greater than a 10-year, 24-hour storm). The Efficacy Report demonstrated that Sump-562 has been successful at intercepting and capturing surface water at the mouth of the West Ravine. The capture capacity was shown to be as much as four times greater than the design criterion of 0.34 inches/hour. Presently, EM Science monitors rainfall precipitation on the property, and conducts a monthly inspection of the sump system. The sump is cleaned of debris approximately two to three times per year.

Storm Water Management Program

In 1987 EM Science initiated a program to collect on-property storm water from process operations areas and redirect the collected storm water to discharge points under the jurisdiction of the City of Cincinnati storm water sewer district. The intent of the program was to mitigate overflows at Sump-562 and to redirect storm water runoff to minimize infiltration into the West Ravine fill. The storm water management program was implemented in four design and construction phases between 1987 and 1988. The program has been successful in limiting the contact of storm water with contaminants in soil and fill beneath the facility. Since 1988, EM Science has continued to maintain and improve its storm water collection, such as placing concrete curbing at the edge of the mouth of the West Ravine. Currently, there is no required monitoring associated with the storm water management program.

French Drain Ground Water Collection System

A French Drain was designed and constructed between 1987 and 1988 by EM Science to intercept and collect contaminated perched ground water migrating eastward in a saturated sand unit (referred to as the Upper Sand Unit in the RI Report). The northern portion of the buried French Drain is located beneath the new aboveground tank farm, which is completely encased by concrete walls. From the new tank farm, the French Drain extends southward to the east of Building 14. Perched ground water collected by the French Drain is directed to the plant wastewater pH/Neutralization facility by Middle and South Lift Stations, and discharged to a City of Cincinnati Metropolitan Sewer District (MSD) sanitary sewer under the plant's current wastewater discharge permit. A North Lift Station located north of the new tank farm is currently not being utilized. The French Drain has demonstrated to be an effective interceptor of contaminated perched ground water flowing beneath the central portion of the facility, as presented in the Efficacy Report. Monthly monitoring includes an inspection of the system and the measurement of ground water elevations in monitoring wells upgradient and downgradient of the French Drain.

Gradient Control Well P6A

A hydraulic gradient control pumping well (P6A) was installed in July of 1992 by EM Science to prevent the eastward migration of contaminated ground water in a silty sandy clay unit (Lower Clay Unit) that extends beneath the French Drain (Figure 1-2). The well is located east of the new tank farm. When the P6A pump is operating, perched ground water is pumped to the plant wastewater pH/Neutralization facility. The gradient control pumping well has attained the goal of mitigating the potential for off-property contaminant migration to the east and southeast. With the concurrence of the Ohio EPA, P6A was shut-off after total VOC concentrations were shown to decrease from approximately 70,000 micrograms/liter (ug/L) to approximately 300 ug/L from 1992 to 1997. Ground water samples collected semi-annually from P6A have not shown an increase in total VOC concentrations since it was shutdown.

Fencing

Additional fencing at the mouth of the West Ravine was constructed in January 1996 as a limited interim action during the RI. The fencing was constructed to completely restrict access to the Outfall, Sump-562, Seep-562 and exposed fill material. With this fencing, it is not possible to trespass onto the property without illegally climbing over a fence line. Access to the property is monitored by 24-hour guard service, which mans a guard station at the front-gate entrance located along Highland Avenue.

Hot Spot Delineation and Removal

Based on the results of the RI Report, EM Science conducted a hot spot delineation and removal interim action on the EM Science property in 1997. The purpose of the interim action was to further delineate, and remove by excavation if warranted, significant localized areas of high concentrations of contaminants detected at or near the surface during the RI. The activities conducted during the interim action were summarized in The Payne Firm's September 29, 1997 Technical Memorandum No. 11, Hot Spot Delineation and Removal Interim Action Report. The TM was approved by the Ohio EPA on December 5, 1997. During the interim action, four cubic yards of mercury-contaminated soil were removed and disposed of off-property at a licensed disposal facility. As documented on TM-11, a localized area of surficial PCB contaminated fill in the former East Ravine area was determined to present no unacceptable risk; and VOC-contaminated soil beneath the former Tank Farm area east of Building 4 was deferred to the FS and Remedial Action phases of work.

1.3.9 Nature and Extent of Contamination

The evaluation of the nature and extent of contamination during the RI included the: 1) division of the Site into four primary areas of VOC soil contamination, two secondary areas of soil contamination, and two ground water groups; 2) identification of the horizontal and vertical extent of contamination; 3) identification of dominant contaminants and relationships between contaminants within each area of contamination; and, 4) identified contaminant distribution patterns including likely sources and current contaminant migration pathways.

The areas of primary VOC contamination are: 1) the middle portion of the West Ravine, including the area near the former Tank Farm; 2) the mouth of the West Ravine, including the Outfall pipe and Sump-562; 3) the area south and east of Building 4; and, 4) the area south of Building 10, including the former pH/neutralization tank. The secondary areas of contamination include: the upper portion of the West Ravine, and the East Ravine. The two perched ground water groups can be characterized as follows:

- Group I includes monitoring wells with no consistent detections of non-background SSPL constituents. The wells are located in portions of the Site that are outside the areas of contamination.

- Group II includes wells with detections of non-background SSPL (Site Specific Parameter List) constituents, primarily associated with the middle portion of the West Ravine, the mouth of the West Ravine, the area south and east of Building 4, and the area south of Building 10. These two groups were used in the characterization of nature and extent and the assessment of risk.

As extensively described in Chapter 4 of the RI report, the assessment of nature and extent of contamination showed that for non-VOC SSPL constituents: 1) detections were generally consistent with levels believed to be representative of urban background in the fill with some evidence of impact to the upper portion of the Upper Till Unit, in all areas of the Site except the East Ravine; and, 2) the fill of the East Ravine contained the highest detections of most non-VOC SSPL constituents.

For the purpose of the FS, the concentration and distribution of VOCs detected during the RI are the more important SSPLs since VOCs are the primary risk and remediation drivers. The assessment of the nature and extent of VOC contamination showed: 1) the upper portion of the West Ravine was only minimally impacted by VOC contamination; 2) VOCs were present within the fill of the middle portion of the West Ravine and the underlying Upper Till and Lacustrine Units; 3) at the mouth of the West Ravine, VOCs were present in the subsurface at the point where the Outfall pipe discharged prior to the installation of Sump-562 but only low levels of VOCs were present in the surface soil/fill; 4) VOCs were detected in perched ground water at the point where the 36-inch storm sewer discharged prior to its removal (near MW505A and MW505B) with evidence of subsurface migration to the area near MW507 and MW508; 5) VOCs were present in the Upper Till Unit and the top part of the Lacustrine Unit in the area south and east of Building 4 and had migrated through the Lacustrine Unit to the area near MW502A and MW502B; 6) VOCs were present in the courtyard of Building 10 down to the Lower Sand Zone and were migrating through the Upper Sand Unit toward the French Drain; and, 7) the East Ravine was minimally impacted by discharge of ground water contaminated with VOCs from the Upper Sand Unit prior to the installation of the French Drain.

The results of the analysis of the nature and extent of VOC contamination by area of contamination are summarized in the following paragraphs:

- The upper portion of the West Ravine is believed to primarily have been filled with soil and construction debris prior to 1956. Detections of VOCs (1,2-DCE, MEK, acetone, benzene, carbon disulfide, chlorobenzene, chloroform, methylene chloride, PCE, toluene and TCE) were largely confined to samples within five feet of the fill/native soil interface. There were also detections of VOCs in the Lacustrine Unit and the Lower Clay Unit, which may be the result of migration from the area south of Building 10. The low levels of the VOC detections and the current storm water management system are likely to severely restrict any movement of VOCs.

- The middle portion of the West Ravine is believed to have been filled with a variety of materials, including off-specification chemicals, industrial and construction debris and the debris from the 1960 fire in Building 5. The former Tank Farm was also located in this area. All SSPL constituent classes are present in the middle portion of the West Ravine. VOCs are detected throughout the fill and in the Upper Till Unit and Lacustrine Unit underlying the fill. Detected VOCs (1,1,2,2-PCA, 1,1,2-TCA, 1,2-DCA, 1,2-DCE, 1,4-dioxane, MEK, acetone, benzene, chlorobenzene, chloroform, ethylbenzene, methylene chloride, PCE, toluene, TCE, vinyl chloride and xylenes) followed a similar distribution pattern. The VOCs were detected in the area(s) of their original source (e.g. Building 4 trench drain, Building 10 process sewer or burial) with evidence of vertical migration through the fill and migration along the fill/native soil interface toward the Outfall. The maximum detections of VOCs occurred at one of the following locations depending upon the original source(s) from which the VOC was released and the mobility characteristics of the compound: near the point where the Building 10 process sewer discharged to the ravine; near the location of the former tank farm; or, near the base of the fill.

- The mouth of the West Ravine was impacted by the filling of the West Ravine, the flow from the Outfall pipe and the presence of S.R. 562. The surface fill in this area showed low levels of VOCs (< 20 µg/kg), SVOCs, D/F, cyanide, metals and PCBs. VOCs were also detected in deeper samples collected from the Lacustrine Unit south of Sump-562. The VOCs detected in the Lacustrine Unit were also detected in water samples collected from the Outfall but not in soil samples or ground water samples collected between the area around Sump-562 and the middle portion of the West Ravine, indicating that the VOC contamination in the Lacustrine Unit near Sump-562 results from infiltration of contamination discharged from the Outfall prior to the installation of Sump-562 rather than subsurface migration from the middle portion of the West Ravine. Similarly, the VOC contamination within the perched ground water monitored at MW503 was believed to result from infiltration of water from Seep-562 rather than subsurface migration. All the contaminants detected in ground water samples from MW503 were also detected in water samples from Seep-562. Prevalent VOCs were detected in the water that discharges from the Outfall and in the Lacustrine Unit at depths of 4 to 12 feet.

- The historical sources of contamination south of Building 10 included leakage from process sewer lines, aboveground tanks and the former pH/neutralization Tank. VOCs are detected to depths of fifty feet in the courtyard area in both soil and perched ground water. Concentrations of detected VOCs (1,1,1-TCA, 1,1,2,2-PCA, 1,2-DCA, 1,2-DCE, 1,4-dioxane, MEK, acetone, benzene, carbon disulfide, carbon tetrachloride, chlorobenzene, chloroform, ethylbenzene, methylene chloride, PCE, toluene, TCE and xylenes) increased with depth in the Upper Till Unit before starting to decrease to non-detectable levels. In the courtyard area, the maximum concentrations of some compounds occur in the Lacustrine Unit or the Lower Clay Unit. South of Building 11, detected VOC concentrations decreased within the Upper Till Unit and increased at the base of the Upper Till Unit and the top of the Lacustrine Unit as a result of transport of VOCs through the Upper Sand Unit before decreasing to non-detectable levels.

- The primary source of VOCs in the area south and east of Building 4 was the Building 4 trench drains which discharge into the ground from approximately 1950 to about 1967. VOC contamination in this area is largely confined to the surface fill and the Upper Till Unit. Detected VOCs follow very similar distribution pattern in this area. The actual extent of the various VOCs is dependent primarily on available mass and mobility characteristics. The maximum concentrations of detected VOCs (1,2-DCA, 1,2-DCE, MEK, acetone, benzene, carbon tetrachloride, chloroform ethylbenzene, methylene chloride, PCE, toluene, TCE and xylenes) occurred either at the northeast or southeast corner of Building 4. The maximum detected concentrations of most VOCs were within the Upper Till Unit at 10 to 20 feet below the ground surface. Generally, the concentrations decreased quickly with the Upper Till Unit and dropped to non-detectable levels within the top portion of the Lacustrine Unit. At the northeast corner of Building 4, VOCs increased within the Lacustrine Unit, possibly as a result of transport of contaminants through the Upper Sand Unit, before rapidly decreasing within 10 feet to non-detectable levels. Below the Lacustrine Unit, there are low level (<25 μg/kg) detections of acetone and toluene. VOCs were detected to the south at VE509 and MW502A.

- The contamination in the East Ravine results from the burial of industrial and construction debris within the ravine and the contamination is primarily confined to the fill itself. Low levels of VOCs were detected, primarily along the western edge of the ravine where VOCs that migrated through the Upper Sand Unit prior to the placement of the French Drain discharged to the ravine. The results of this migration were detected from the area near from P6 south to MW15. SVOCs, metals, cyanide, PCBs and D/F were detected within the fill with no distinct concentration gradients as were observed in the other source areas. The relatively immobile nature of these compounds has restricted migration preventing both contamination of native soil and formation of concentration isopleths within the fill. The contamination is to a large degree where it was originally placed within the fill. VOCs (1,1,2,2-PCA, 1,1-DCA, 1,2-DCA, 1,2-DCE, 1,4-dioxane, MEK, acetone, benzene, carbon disulfide, ethylbenzene, isobutyl alcohol, methylene chloride, PCE, toluene, TCE and xylenes) were detected in both fill and native soil.

1.3.10 Contaminant Fate and Transport

The overall objective of the contaminant fate and transport analysis during the RI was to evaluate the potential for Site contamination to reach points where it can pose a risk to human health or the environment. The fate analysis focused on the mobility and longevity of certain soil and ground water contaminants detected beneath the Site and their degradation products.

The implementation of the French Drain, P6A, Sump-562, and the storm water management program by EM Science before the RI was initiated has significantly minimized the off-property migration of SSPL contaminants. The data needs for the assessment of contaminant migration within the Perched Ground Water System, therefore, were developed from the results of the RI field investigation, and the objectives of the baseline risk assessment. The SGM and the results of the nature and extent of contamination investigation demonstrated the silt and clay rich Perched Ground Water System has limited horizontal and vertical potential migration pathways, and that the Confining System is an effective barrier between the Perched Ground Water System and the Norwood Trough Aquifer. The specific pathways addressed in the analysis of perched ground water migration were: 1) contaminants migrating from the area south of Building 10 to the eastern property boundary, which yielded conservative upper bound estimates of the potential concentrations at the eastern property boundary; 2) contaminants migrating in perched ground water at off-property locations in the southern portion of the Site; and, 3) contaminants migrating vertically from primary areas of VOC contamination.

The results of the analysis of migration of contaminants from the area south of Building 10 to the eastern property boundary were used in the evaluation of the potential risk to a future off-property residential user of ground water. The evaluation of potential for vertical transport from the areas of contamination yielded breakthrough times within certain geological units in the SGM.

The results of the contaminant transport analysis in perched ground water are conservative approximations since assumptions incorporated into each step of the transport model development were made so as to not underestimate the potential concentrations present at, or the time periods required to reach, the receptor locations. Conservative assumptions were made with respect to the model parameters, the variability of current Site physical characteristics, and the future stresses applied to the modeled systems. The results of the contaminant transport analysis indicated that only a limited number of the more mobile indicator contaminants evaluated are present in sufficient quantity (i.e., total mass) and have mobility characteristics such that the potential exists for measurable quantities of these contaminants to be transported to the eastern property boundary. The transport analysis indicated that the physicochemical characteristics of less mobile contaminants (such as PCBs, dioxins and furans and many SVOCs) result in transport times through the Vadose Zone to the Upper Sand Unit that are sufficiently great (500 years or more) that migration of these contaminants to receptor locations was not considered to be a risk concern. The results of the transport evaluation from the area south of Building 10 to the eastern property boundary were used within the baseline risk assessment. The evaluation of the potential for vertical contaminant migration indicated that breakthrough times for transport of contaminants vertically from the areas of contamination were greater than 10,000 years assuming that the mechanisms required for transport are present. Review of the geological and hydrogeological data supports the conclusion that mechanisms for vertical migration are limited to diffusion and minimal infiltration. In addition, there is a very low to negligible potential that the Norwood Trough Aquifer would ever be impacted by contaminants detected below the Site due to the limited mechanisms for vertical migration and a limited amount of total contaminant mass.

1.3.11 Natural Attenuation Evaluation

Although U.S. EPA recognizes that "the natural attenuation processes that are at work in such a remediation approach [as monitored natural attenuation] include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and ground water," U.S. EPA expects that monitored natural attenuation "will be used in conjunction with active remediation measures (e.g., source control), or as a follow-up to active remediation measures that have already been implemented."

After the RI, a preliminary assessment of monitored natural attenuation was conducted to determine if conditions favorable to reduction of the concentrations of VOCs are present in media beneath the site. The methods and results of this assessment, which are summarized below, were presented to the Ohio EPA in the Payne Firm's July 2, 1999, Natural Attenuation Technical Memorandum No.17. Ohio EPA comments dated August 5, 1999 were received and a revision to TM-17 was submitted in January 2000. The assessment included evaluation of historical site data (including pre-RI, RI, and post-RI analytical data and potential effects from interim actions), analysis of ground water samples from four areas of the site for natural attenuation indicator parameters, and microcosm studies to assess the biodegradation potential of the naturally-occurring site bacteria.

As presented in TM-17, four discrete areas of the Site were examined based on areal extent of VOCs and hydrogeologic differences:

- Monitored Natural Attenuation Area One (MNA Area 1) – Upper Sand Unit D1 (Perched Zone I), from the central portion of the site to the French Drain;

- Monitored Natural Attenuation Area Two (MNA Area 2) – Sand seams in the upper portion of Lacustrine Unit D2 (Perched Zone II), at the mouth of the West Ravine;

- Monitored Natural Attenuation Area Three (MNA Area 3) – Sand seams in the lower portion of Lacustrine Unit D2 (Perched Zone II), downgradient of the mouth of the West Ravine; and,

- Monitored Natural Attenuation Area Four (MNA Area 4) – Lower Clay Unit D3 (Perched Zone II) beneath the filled East Ravine.

Individual VOCs found at the Site were evaluated within five associated chemical groupings (four comprised of chlorinated compounds, one of non-chlorinated aromatics) for purposes of qualitatively assessing the potential significance of biological or chemical processes of natural attenuation in reducing the mass, toxicity, mobility, volume, or concentration of the VOCs in soil and ground water at the Site. This assessment was completed in part by evaluating the ratio of chlorine-heavy to chlorine-light compounds within a group over time. Within each of the four groups of chlorinated VOCs, chlorine-heavy compounds (three or four chlorine atoms per molecule) normally degrade to chlorine-light compounds (one or two chlorine atoms), although the potential direct release of chlorine-light compounds at the Site requires caution in interpretation of changes in chlorine-heavy to chlorine-light ratios over time. The five VOC groups consist of:

- Chloroethenes (CEs) contain two carbon atoms joined by a double bond, one to four chlorine atoms, and a sufficient number of hydrogen atoms to stabilize the molecule. The compounds are tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-DCE), and vinyl chloride (VC). Within the group, more-chlorinated compounds (PCE and TCE) degrade to less-chlorinated forms (1,1-DCE, 1,2-DCE and VC). Chlorine-heavy CEs tend to degrade more readily under reducing conditions.

- Group I Chloroethanes (CA-1s) contain two carbon atoms joined by a single bond, one to three chlorine atoms, and a sufficient number of hydrogen atoms to stabilize the molecule. Within the group, more chlorinated compounds degrade to less chlorinated forms. One example of a breakdown path is 1,1,1-trichloroethane (1,1,1-TCA) to 1,1-dichloroethane (1,1-DCA), which may eventually decompose to chloroethane and/or directly to innocuous compounds.

- Group II Chloroethanes (CA-2s) contain two carbon atoms joined by a single bond, two to four chlorine atoms, and a sufficient number of hydrogen atoms to stabilize the molecule. Within the group, 1,1,2,2-tetrachloroethane (1,1,2,2-PCA) degrades to 1,1,2-trichloroethane (1,1,2-TCA) and then to 1,2-dichloroethane (1,2-DCA). The latter compound is relatively persistent but can degrade to innocuous byproducts over time.

- Chloromethanes (CMs) contain a single carbon atom, one to four chlorine atoms, and a sufficient number of hydrogen atoms to complete the molecule (i.e., carbon tetrachloride [PCM], chloroform [TCM], methylene chloride [DCM], and methyl chloride [CM]). These compounds are fairly stable. Generally, decomposition rates of PCM slow at TCM or DCM.

- BTEX compounds are benzene, toluene, ethylbenzene, and xylenes. Their basic structure is the benzene ring, composed of six carbon and six hydrogen atoms. In the three other compounds, one or more side chains replace one or more of the hydrogen atoms. Aerobic degradation is generally more rapid than anaerobic for the same compound in this group.

As discussed in Section 1.3.8, interim actions have been performed at the Site to control the primary migration pathways. These actions have had various effects on the concentrations of detected VOCs at different times and were evaluated as part of the assessment. The interim actions have included:

- A ground water collection sump was installed in 1983 and continues to operate at the mouth of the West Ravine. The collection sump intercepts Vadose Zone Fill and sand seams in Lacustrine Unit D2. The magnitude of detected contamination at the sump appears to have decreased slightly since operations began.

- A French Drain was installed in 1987-1988 to intercept ground water from the Upper Sand Unit D1 and continues to operate. This system is located at the eastern part of the site between the central manufacturing area and the East Ravine. There has also been a wastewater closeout at the Site to control storm water discharges. This system has reduced recharge to the Upper Sand Unit. Initial discharges from the French Drain were much greater than the current discharge, suggesting dewatering of a portion of the perched aquifer. Dewatering of part of the Upper Sand Unit was evidenced by subsequent drying or reduced yield of several wells screened in the unit. A concurrent decrease in contaminant concentrations by one to two orders of magnitude, and in the variety of detected contaminants appears to have also occurred.

- A pump was installed in Piezometer P6A in 1992. The pump extracted residual contaminated ground water from the Lower Clay Unit D3. This unit is believed to have been contaminated from Upper Sand Unit D1 prior to installation of the French Drain. P6A was shut off in 1997 following demonstration of its effectiveness and the reduced off-property contaminant migration potential.

In addition, trend analyses of historical ground water data were performed to provide more quantitative evaluations of VOC concentration changes over time. For this evaluation, individual VOCs found at the Site were reviewed in groupings of Total Chlorinateds (CES, CA-1s, CA-2s), total Chloromethanes (CMs) and Total BTEX.

The preliminary assessment of monitored natural attenuation identified variable results for purposes of qualitatively assessing the potential significance of biological or chemical processes of natural attenuation in reducing the mass, toxicity, mobility, volume, or concentration of the VOCs in soil and ground water at the Site. The observed effects from the review of existing data for the Site indicate the following:

- The evaluation of historical Site data (including analytical data and potential effects from interim actions) identified:

  - Order of magnitude reductions in the magnitude of contamination at MNA Area 1 following installation of the French Drain;

  - Elimination of CA-1s at MNA Area 2 following installation of the French Drain;

  - Order of magnitude reductions in the magnitude of contamination at MNA Area 3 following installation of the Collection Sump;

  - Order of magnitude reductions in the magnitude of contamination at MNA Area 4 following installation of the French Drain and Pumping at P6A;

  - Change in proportion of CEs from chlorine-heavy to chlorine-light compounds at each area; and,

  - Change in proportion of CA-1s and CA-2s from chlorine-heavy to chlorine-light compounds at MNA Area 1.

- The analysis of ground water samples from four areas of the site for natural attenuation indicator parameters verified favorable dissolved oxygen, methane, oxidation-reduction potential, chloride, and ferrous iron levels at MNA Areas 1, 2, and 3.

- Microcosm studies to assess the biodegradation potential of the naturally-occurring site bacteria suggest bacteria in soil at MNA Area 1 could have an effect on CEs.

In summary, the assessment demonstrates that there are conditions beneath the Site that suggest that biological and chemical processes of monitored natural attenuation are occurring, or have the potential to occur to reduce the mass, toxicity, mobility, volume, or concentration of some VOCs (particularly CEs and CA-1s) in soil and ground water.

2.0 REMEDIAL ACTION OBJECTIVES

2.1 INTRODUCTION

Conclusions in the RI Report document that portions of the soil, fill and perched ground water beneath the Site contain chemical constituents at levels that exceed risk-based standards, or conditions exist that are not in compliance with applicable or relevant and appropriate requirements (ARARs) under federal or state regulations for protection of human health and the environment. As a result, remedial action is warranted at the Site. This section establishes remedial action objectives (RAOs) to guide the SFS through the remedial action development, screening, and comparison process for alternatives.

RAOs are either medium-specific or operable unit-specific goals for protecting human health and the environment. Each RAO is written so that one or more remedial alternatives can be developed to mitigate the unacceptable risks identified in the RI. However, the RAO does not specify a remedial action. Typically, separate RAOs are developed for human health receptors and for ecological receptors. No ecological RAOs were developed in this FS because no exposure routes were identified at the Site that involve direct contact with, ingestion of, or uptake of contaminants in soil by ecological receptors.

This section identifies RAOs for contaminated media both on the EM Science property and outside the south fenceline of the property on the S.R. 562 right of way. Information for this section was obtained from the RI, "Technical Memorandum No. 10 - RAO Technical Memorandum and Initial Technology Screening" (RAO TM 10), and from "Technical Memorandum No. 14 – Alternatives Array Report (AA Report TM 14). Ohio EPA previously approved RAO TM 10 without condition. Ohio EPA comments regarding the AA Report TM14 were to be incorporated into the FS Report. In accordance with the National Contingency Plan (NCP) and Ohio EPA's policy on evaluation criteria to support remedy selection (DERR-00-RR-019), RAOs were developed with priority given to the following threshold criteria:

1. Overall protection of human health and the environment; and

2. Compliance with applicable or relevant and appropriate laws, rules, standards, and criteria

The following subsections detail the approach used to address the threshold criteria in developing the RAOs, corresponding preliminary remediation goals (PRGs), and the resulting areas subject to remediation.

2.2 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Information presented in the RI Report, in particular Chapter 6, the Baseline Human Health Risk Assessment (HHRA), quantified the potential risks under several current and future exposure scenarios. In the RI, Tables 6-6 through 6-17 (see Appendix A) presented the risk scenarios and risk values from which the principal threats or "risk drivers" for remedial action are calculated. Risk drivers are derived from the reasonable maximum exposure (RME) to a contaminant expressed as an excess lifetime cancer risk (ELCR) or hazard index (HI) given the reasonably anticipated land use. The HHRA evaluated risk under three current (EM Science workers, RME off-site receptors [residents], and trespassers) and five future (construction workers, commercial/ industrial [C/I] workers, and RME off-site receptors, as well as residential users of groundwater on-site and at the eastern property boundary) exposure scenarios.

For non-carcinogens, the threshold criterion for exposure to systemic toxicants is an HI equal or less than 1.0. For known or suspected carcinogens, the threshold criteria are concentration levels that represent an excess upper bound lifetime cancer risk of 1E-06 (ELCR 10-6). Table 2-1 presents a summary of the maximum risk values, and associated exposure scenario resulting in that maximum risk, determined by the HHRA for on-site exposure from each of the Site areas or media. The values shown on Table 2-1 represent the total risk, based on multiple SSPL parameter groups, for the specific exposure scenario resulting in the highest risk for a given area. The ELCR 10-6 level is selected as an appropriate threshold for human health protection because of the presence of multiple carcinogens and multiple exposure pathways. While Table 2-1 is conservative in that only maximum risks are given, other exposure scenarios also generated risks greater than an ELCR of 1E-06.

Table 2-2 presents a summary of the HHRA analysis of risks posed to off-site receptors from inhalation of VOCs and fugitive dust from the Site under non-excavation conditions. The scenario for off-site exposure considered both current conditions and assumed future conditions (unpaved).

It is important to note that the RI report grouped subsurface materials and non-paved surface materials at the EM Science site into various "soil" and "fill" units. The terms "soil" and "fill" are used to differentiate native, in-place soils from emplaced materials that include soil as well as various forms of debris, chemical containers and other material. The HHRA indicated that impacts to native soils that resulted in unacceptable human health risks were limited primarily to areas of significant VOC contamination (Middle West Ravine, area south of Building 10, and the area south and east of Building 4). The HHRA indicated that native soils in the Upper West and East Ravine areas did not appear to be as significantly impacted by contamination.

The HHRA indicated that the SSPL substances that resulted in the highest risk levels were organic compounds, primarily VOCs and SVOCs in soil and fill, and VOCs in groundwater. The HHRA also concluded that risk from inorganics, primarily driven by arsenic, exceeded the ELCR 10-6 level for fill material in each of the various sub-portions (upper, middle, mouth) of the West Ravine area and in the East ravine area for one or more of the following: current and future on-site workers, construction workers, trespassers, and RME off-site receptors (residents). In some portions of the Site, risk from arsenic comprises the greatest portion of the total ELCR. The magnitude of detected concentrations of arsenic relative to background concentrations varies among the various areas fill areas, and also varies with depth within each individual area; however, it is significant to note that the HHRA indicated that the ELCRs for each of the areas listed in Table 2-1 are each greater than 10-6 without arsenic.

2.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

In addition to protecting human health and the environment, a potential remedial action must comply with pertinent environmental laws known as ARARs. ARARs consist of regulations, standards, criteria, or limitations promulgated under federal and local environmental laws. An ARAR may be either applicable, or relevant and appropriate, but not both. ARAR identification considers site-specific factors including potential remedial actions, contaminants at the site, physical characteristics of the site, and the site location. ARARs are usually divided into three categories: chemical-specific, location-specific, and action-specific. In 40 CFR 300.5, the NCP defines the terms "applicable" and "relevant and appropriate" as follows:

> Applicable requirements: mean those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically include a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a site.
>
> Relevant and appropriate requirements: mean those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site, address problems or situations sufficiently similar to those encountered at the site (relevant) that their use is well suited (and appropriate) to the particular site.

A requirement is applicable if it specifically addresses or regulates the hazardous substance, pollutant, contaminant, action being taken, or other circumstance at the site. To assess whether a particular requirement would be applicable, it is necessary to evaluate specific jurisdictional prerequisites of the statute or regulation. All pertinent jurisdictional prerequisites must be met for the requirement to be applicable, including the following:

Who, as specified by the regulation, is subject to its authority

The types of substances and activities listed as falling under the authority of the regulation

The period during which the regulation is in effect

The types of activities the regulation requires, limits, or prohibits

If jurisdictional prerequisites are met, the requirement is applicable. If not, the next step is to consider whether the requirement is relevant and appropriate. A requirement may be relevant but not appropriate for a specific site. Only those requirements that are determined to be both relevant and appropriate are ARARs. Portions of a requirement may be relevant and appropriate even if a requirement in its entirety is not. The criteria for evaluating whether a requirement is relevant and appropriate include the following:

The purpose of the requirement and the purpose of the remedial action

The medium regulated or affected by the requirement and the medium contaminated or affected at the site

The substances regulated by the requirement and the substances found at the site

The actions or activities regulated by the requirement and the remedial action at the site

Any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the site

The type of place regulated and the type of place affected by the release or remedial action

The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the remedial action

Any considerations of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the site

State laws pertaining to source water protection, groundwater protection and air pollution control as well as waste identification and handling are the primary sources of ARARs for this site. Table 2-3 presents a detailed list of ARARs, their regulatory citations and a brief analysis of the impact of each ARAR on the alternatives presented in this FS. The ARARs in Table 2-3 are drawn primarily from the draft FS (Appendix B) and AA Report, TM 14, submitted by EM Science. The discussion that follows examines some of the more significant ARARs that are pertinent to the remedial actions in this SFS. The ARARs were evaluated to determine the specific requirements of each ARAR and the circumstances that would trigger implementation of that ARAR. Table 2-3 also contains three non-media-specific or non-environmental regulations that are ARARs.

2.3.1 Surface Water and Groundwater Quality Protection ARARs

The results of the HHRA identify releases of contaminated groundwater from the site as a principal threat from the EM Science site. State statutes and regulations that pertain to these releases as ARARs and through the state orders are discussed in this section.

The release of VOCs from sources at EM Science to groundwater and surface water at the site constitute violations of Section 6111 of the Ohio Revised Code. Groundwater is found directly underneath the site, and the nearest regulated surface water body is the West Fork of Duck Creek, approximately 600 feet south of the property. Groundwater affected by site contaminants is discharged at Seep C to the 84-inch storm sewer, located in the bottom of the East Ravine, which eventually discharges to the West Fork of Duck Creek. In addition, groundwater/ leachate discharged from the Outfall to Sump 562 and from Seep 562 at the Mouth of the West Ravine, which is typically pumped to the treatment facility, can bypass treatment during heavy precipitation events. This overflow discharges to the 27-inch storm sewer that flows southward from the site and joins the 84-inch storm sewer, eventually discharging to Duck Creek.

Specifically, ORC Section 6111.04(A)(1) states:

> "No person shall cause pollution or place or cause to be placed any sewage, sludge, sludge materials, industrial waste, or other wastes in a location where they cause pollution of any waters of the state."

The important definitions (found in ORC Section 6111.01(A), (D) and (H)) in this prohibition are "pollution," "industrial wastes or other wastes" and "waters of the state." Because the RI and risk assessment have shown that the facts of the releases of VOCs at the EM Science site meet these definitions, ORC Section 6111 is a major ARAR, as well as a primary driver of remedial action at the site. Any action taken to address the RAOs for soil contamination, or Group II or Eastern Boundary groundwater should first eliminate current pollution of waters of the state and secondly, should comply with Section 6111.04(A)(1) as an action-specific ARAR by discharging any extracted and/or treated groundwater or surface water without causing additional pollution of waters of the state. The specifics of complying with ORC 6111 as an ARAR are documented in Ohio EPA's guidance entitled: "National Pollution Discharge Elimination System: Wastewater Discharges Resulting from Clean-up of Response Action Sites Contaminated with Volatile Organic Compounds" dated September 22, 1994 (Ohio EPA, 1994). The guidance is applicable to any cleanup action "which results in the discharge of VOC-contaminated wastewater to surface waters of the state, to a sanitary or storm sewer system, or hauling off-site any such wastewater to a POTW." On a practical level, compliance with ORC 6111 requires obtaining the approval of the Director of Ohio EPA for remedial action plans in accordance with ORC 6111.45. According to the guidance, "Depending upon the approved methods of treatment/disposal, National Pollutant Elimination System (NPDES) permits and Permits to Install (PTI) may be required." Therefore, it is likely that a PTI/PTO permit, or permit modification will be required if the preferred remedial action includes a component that falls into one of the discharge categories outlined in the guidance. The permitted discharge will be required to meet best available treatment technology/best available demonstrated control technology (BATT/BADCT) as defined by Ohio EPA.

It is important to note that the Ohio EPA 1994 guidance cites other state statutes and regulations as applicable to groundwater and surface water protection. These requirements are considered ARARs for this site:

> OAC 3745-31-02: Requirements; (OAC 3745-31-02 is the implementing regulation for permits under ORC Section 6111)
>
> ORC 3734.13: Enforcement orders; emergency orders; procedure upon violation.
>
> ORC 3734.20: Investigation of conditions where waste is treated, stored or disposed of; action or measures by director.
>
> ORC 3750.06: Owner or operator of facility or vessel to give notice of release of hazardous substance; follow-up notice.

A detailed explanation of how alternatives will meet the final groundwater and surface water ARARs will be included in the decision document (DD) in the description of alternatives section.

2.3.2 Air Pollution Control ARARs

Air pollution control ARARs are pertinent to the remedial actions proposed in this SFS in two ways. First, any remedial action that involves significant excavation or construction activities on site will likely generate fugitive dust emissions that could create an air quality problem. The limitations on fugitive dust emissions in OAC 3745-17-07 and OAC 3745-17-08 are directly applicable to these excavation and construction activities. These regulations prohibit the remedial activities from creating a public nuisance and require the application of reasonably available control technology (RACT) to accomplish this goal. RACT technologies include application of water, oil or other dust suppression materials, or the use of containment or collection equipment to capture the fugitive dust.

Secondly, ARARs that pertain to air emission sources may be applied to potential air emissions from equipment needed to treat contaminated leachate or groundwater before it leaves the site. Specifically, certain sections of OAC 3745-21-09 may apply or be relevant and appropriate to air pollution control equipment that removes VOCs from the leachate or groundwater extracted from the site. It is not likely that such equipment will meet the definition of a stationary source as defined by the rule, thereby requiring a permit to install (PTI) a new air pollution source. However, the substantive requirements of the rule may be suitable for restricting the emissions from the treatment unit. Any air pollution control equipment will be chosen or designed to comply with the substantive standards.

2.3.3 Hazardous Waste and Solid Waste ARARs

State hazardous and solid waste requirements that are considered ARARs for the EM Science site can be divided into three categories:

ARARs related to materials generated at the site and transported off-site,

ARARs related to handling or storage of materials on-site, and

ARARs related to post-remediation contamination that remains at the site.

Although the West Ravine and East Ravine areas were not operated as permitted solid waste landfills, the materials placed in the West Ravine and East Ravine, as well as the soil and fill contaminated by the migration of chemicals from those materials, are considered to be wastes under OAC 3745-51-02(A)(1). If they are excavated, these "wastes" have the potential to be considered hazardous wastes under OAC 3745-51-03 (A)(2)(a) if they are "listed" hazardous wastes as defined in OAC 3745-51-30 through 3745-51-35 or if they exhibit the characteristics defined in OAC 3745-51-20 through 3745-51-24. However, EM Science reports that no records are available regarding the wastes disposed of in the ravines. For these reasons, it appears that hazardous waste regulations would only be applicable in the event that the materials are (1) excavated and (2) exhibit the aforementioned hazardous characteristics. During the final remedial action, wastes will be characterized using the methods specified in OAC 3745-52-11 (A) through (D).

If hazardous wastes are determined to be present at the site, the final remedial action must comply with all State ARARs pertaining to the generation, handling and disposal (including off-site disposal) of hazardous wastes. If the remedial action includes leaving residual hazardous wastes at the site, State ARARs pertaining to final closure of hazardous waste units, such as construction specifications for caps and leachate collection, may be relevant and appropriate. These requirements are found in relevant portions of OAC 3745-54 and 3745-55 dealing with post-closure care and corrective action.

In addition, all hazardous wastes transported from the site must be transported in compliance with the requirements of OAC 3745-52-20 through OAC 3745-52-33, which address packaging, manifesting and placarding of hazardous waste for transport. Management and handling of the wastes on-site will be governed by regulations that include requirements for security, design and operational standards, and emergency planning. These ARARs are generally found in 3745-54 and 3745-55 and are presented in additional detail in Table 2-3.

If the wastes found at the site are determined not to be hazardous, State ARARs pertaining to the generation, handling and disposal of solid wastes and closure of solid waste landfill facilities are considered relevant and appropriate. These solid waste ARARs are found in OAC 3745-27 and are listed in Table 2-3, and would apply similarly to the hazardous waste management ARARs described above. For example, technical performance standards that drive required design, construction, and O&M specifications for final closure of a solid waste landfill are considered pertinent to a containment remedy at EM Science.

2.4 REMEDIAL ACTION OBJECTIVES

The approach to developing RAOs outlined in RAO TM 10 was to divide the contaminated soil and fill material at EM Science into four "primary areas of VOC contamination" (the Middle West Ravine, the mouth of the West Ravine, the area south of Building 10 and the area south and east of Building 4) and two secondary areas of contamination (the Upper West Ravine and East Ravine). Groundwater contamination was addressed as "Group II Groundwater" and "Eastern Boundary Groundwater." Group I groundwater, which is generally located outside the area of contamination was determined not to present unacceptable risk associated with the site.

For purposes of discussions of RAOs, remedial alternatives, and costs in this FS, the collective term "soil/ fill" is used as a generic description of areas containing heterogeneous fill and contaminated soil (either native or emplaced with the other fill materials). The specific terms "fill" or "soil" is used in situations where RAOs and alternatives are focused exclusively on either emplaced fill or native soil, respectively.

The nature of the soil and fill contamination at these areas and the common risk scenarios they share allow for the further combination of these areas (see Figure 2-1), to simplify the development of alternatives to achieve the RAOs. Therefore, this SFS combines the areas and distinguishes between two groundwater areas of contamination. RAOs are developed for the following areas, which are described in detail in Section 2.4.1 through 2.4.7:

Area 1: Off-property Mouth of the West Ravine Soil/Fill
Area 2: On-property Mouth of the West Ravine Soil/Fill
Area 3: Combined Middle West Ravine, consisting of:
Middle West Ravine Soil/Fill
Native soil in area south of the Building 10, and
Native soil in the area south and east of Building 4
Area 4: Upper West Ravine Fill
Area 5: East Ravine Fill
Group II (Perched) Groundwater and Seeps
Eastern Boundary Groundwater

The RAOs for each area are summarized in Table 2-4. The primary source for the RAOs is from RAO TM 10, and a summary table presented therein (Table 6-1). RAOs are based on (1) the contaminant(s) of concern identified through the RI, (2) the exposure route and receptor(s), and (3) an acceptable contaminant concentration or range of concentrations for each exposure pathway and media based on risk assessment. Protectiveness may be achieved by (1) limiting or eliminating the exposure pathway; or (2) reducing contaminant concentrations. This SFS evaluates remedial alternatives for both.

2.4.1 Area 1: Off-Property Mouth of the West Ravine Soil/Fill

Area 1 is located on ODOT property associated with S.R. 562. Releases in Area 1 from the EM Science site include perched groundwater/leachate from Seep 562 and the outfall, contaminated soil, and fill from historical disposal activities in the Mouth of the West Ravine. The maximum ELCR from on-site exposure calculated in the HHRA is 5.25E-06 based on direct contact exposure by a trespasser (Table 2-1). The maximum ELCR calculated in the HHRA under the RME off-site exposure scenario is 3.07E-05 by the inhalation pathway. The other receptor scenarios in the HHRA (construction worker, EM Science worker, and ODOT worker) also resulted in an ELCR greater than 10-6. The primary risk drivers in the soil of Area 1 are VOCs, inorganics, and dioxins and furans.

The RAOs for contaminated soil/fill in Area 1: Off-Property Mouth of the West Ravine are:

- Reduce exposure via direct contact to the fill of the Off-Property Mouth of the West Ravine to prevent an ELCR > 10-6 and HI >1
- Remove and properly dispose off-property waste materials (i.e. solids, non-soil materials)

2.4.2 Area 2: On-Property Mouth of the West Ravine Soil/Fill

Area 2 is the remaining portion of the Mouth of the West Ravine that is on-property. This portion of the Mouth of the West Ravine contains the majority of the containers of off-spec chemicals that were disposed in the ravine. The HHRA considered exposure scenarios for the off-property Mouth of the West Ravine, however, because of the similar conditions and contiguous nature of the west ravine, the RAO for the waste and soil/fill in Area 2: On-Property Mouth of the West Ravine is the same as for Area 1, namely:

- Reduce exposure via direct contact to the fill of the On-Property Mouth of the West Ravine to prevent an ELCR > 10-6 and HI >1

2.4.3 Area 3: Combined Middle West Ravine Soil/ Fill

Area 3 encompasses areas where fill/waste was placed in the Middle West Ravine and areas with native soil contamination, occurring at depths up to 30 feet below ground surface (bgs) (area south of Building 10, the area south and east of Building 4, and beneath the fill of the Middle West Ravine). This area includes the "hot spot" in the area of the former Tank Farm.

The RI report concluded that the primary VOCs of concern were: chloroethane; chloroethene; chloromethane; acetone; 1,4-dioxane and benzene, toluene, ethylbenzene, and xylene (BTEX) compounds. Data gathered during the RI indicate that these compounds have migrated from source areas in the past, are currently migrating, and have the greatest potential for future migration. VOCs present in the Vadose Zone south of Building 10 are currently migrating through the Upper Sand Unit toward the French Drain. Site data indicate that the VOCs present in the West Ravine soil and fill are currently migrating to groundwater through the fill to the off-property outfall near Sump-562, and off-property southward through the underlying sands of the upper lacustrine unit.

The HHRA conducted for on-site exposure indicated that the future risk of inhalation and dermal contact with contaminants, primarily VOCs and SVOCs for commercial/industrial workers, EM Science workers and trespassers exceeds 1.0E-06 (the ELCR = 5.13E-04, Table 2-1). The ELCR (2.45E-04, Table 2-2) from future exposure of off-site residents to contaminants (primarily VOCs) via inhalation also exceeds 1.0E-06, although the risk scenario is less likely than the worker's exposure. It should also be noted that there are no land use controls currently in place that eliminate potential on-site residential exposure scenarios; however, the HHRA was based in part on the assumption that the site would remain industrial or commercial and therefore the HHRA did not evaluate risk to potential future on-site residents from direct contact to site fill or soil.

The RI indicated that in the area south of Building 10, VOCs might leach to groundwater in the upper sand unit and migrate to the eastern property boundary. This potential for migration is currently limited by the French drain and availability of the supplemental pump and treat system (Well P6A) that may be used to contain contaminated groundwater in deeper portions of the upper sand unit. There currently are no restrictions regarding future use of groundwater as a source of potable water supplies, however, there may be local ordinances prohibiting the use of residential wells. The HHRA indicated that ingestion of groundwater impacted by leaching of VOCs in the vicinity of Building 10 by a hypothetical future groundwater user in the vicinity of the eastern property boundary resulted in an ELCR greater than 1E-06 (see Section 2.4.7). For this reason, actions to mitigate the potential for continued leaching of contaminants from soil and fill in the Combined Middle West Ravine area to groundwater are necessary.

The HHRA found that inhalation and ingestion of contaminants, primarily inorganics (arsenic), in the soil and fill south and east of Building 4 by future commercial/industrial workers, as well as by future off-site residents, result in ELCRs of 1.21E-05 (Table 2-1) and 3.06E-05 (Table 2-2) ELCR, respectively.

Based on these observations, the RAOs for Area 3: Combined Middle West Ravine, are:

- Reduce exposure via direct contact to the fill of the Combined Middle West Ravine to prevent an ELCR > 10-6 and HI >1.
- Reduce exposure via inhalation of VOCs and suspended particulate matter from the fill of the Combined Middle West Ravine to prevent an ELCR > 10-6 and HI >1

- Reduce infiltration to minimize the volume of groundwater that contacts contaminated soil/fill to prevent leaching

2.4.4 Area 4: Upper West Ravine Fill

The HHRA indicated that risk drivers in the Upper West Ravine area include SVOCs and inorganics in the fill. The risk drivers in this portion of the Site are generally less mobile than VOCs and therefore have less potential to impact perched groundwater.

The HHRA indicated that direct contact by commercial/industrial workers, primarily with base-neutral (B/N) SVOCs commonly referred to as polynuclear aromatic hydrocarbons (PAHs) and arsenic, results in risk as high as 1.02E-05 ELCR (Table 2-1). PAHs are generally immobile and insoluble, creating a low-, rather than high-level threat as defined by the NCP. In the NCP, the expectation for low-level threats is that they will be addressed by engineering controls rather than treatment. The HHRA indicated that the ELCR from inhalation of substances (primarily arsenic) in the fill of the Upper West Ravine by future off-site residents would be 3.00E-05 (Table 2-2).

Therefore, the RAOs for fill in Area 4: Upper West Ravine are:

- Reduce exposure via direct contact to the fill of the Upper West Ravine to prevent an ELCR > 10-6 and HI >1
- Reduce exposure via inhalation of suspended particulate matter from the fill of the Upper West Ravine to prevent an ELCR >10-6 and HI >1

2.4.5 Area 5: East Ravine

The HHRA indicated that risk drivers in the East Ravine include PCBs, SVOCs, and inorganics in the fill. Native soil in the east ravine was not found to pose unacceptable risk levels due to contamination.

PCBs detected during the RI appear to have been concentrated in a localized area. The HHRA indicated that potential exposure to PCBs in East Ravine fill resulted in an HI greater than one and therefore resulted in unacceptable risk, based on a single elevated concentration of 16 mg/kg of PCBs used as the exposure point concentration (EPC). However, subsequent soil sampling conducted during the FS and reported in TM-11 indicated that the location of the single elevated concentration used as the exposure point concentration in the HHRA had been removed during the installation of boring VE402/ VZ407 and did not indicate widespread PCB contamination.

The HHRA indicated that dermal contact by commercial/industrial workers with SVOCs, primarily PAHs detected sporadically in the East Ravine fill, was the primary contributor to risk as high as 5.14E-05 ELCR (Table 2-1). PAHs are generally immobile and insoluble, creating a low-, rather than high-level threat as defined by the NCP. In the NCP, the expectation for low-level threats is that they will be addressed by engineering controls rather than treatment. The HHRA indicated that the ELCR from inhalation of substances (primarily arsenic) in the fill of the East Ravine by future off-site residents would be 3.00E-05 (Table 2-2).

Therefore, the RAOs for fill in the East Ravine area are:

- Reduce exposure via direct contact to the fill of the East Ravine through containment to prevent an ELCR > 10-6 and HI >1
- Reduce exposure via inhalation of suspended particulate matter from the fill of the East Ravine through containment to prevent an ELCR >10-6 and HI >1

2.4.6 Group II (Perched) Groundwater and Seeps

Group II groundwater is perched groundwater at the site that is impacted by site contamination as a result of leaching from contaminated soil. Group II groundwater is found beneath the central and southern portions of the property and migrates toward the eastern and southern boundaries of the site. The primary contaminants for Group II groundwater are VOCs, including benzene, 1,2–dichloroethene (1,2-DCE), tetrachloroethene (PCE), chloromethanes (carbon tetrachloride, chloroform and methylene chloride), and 1,4-dioxane. Contaminated Group II Groundwater is present at the soil/fill interface in the Middle West Ravine, in the Upper Sand Unit in the areas near Buildings 4 and 10 east to the French Drain, in the Lacustrine Unit in the areas near Buildings 4 and 10, and south of the southern property boundary. Effective remediation of the Group II Groundwater will require prior or simultaneous remediation of the soil and fill of Area 3: Combined Middle West Ravine.

Perched groundwater at the base of the fill of the West Ravine likely flows along the soil/fill interface toward the Outfall where it is discharged to Sump-562 or infiltrates the Lacustrine Unit. Once the water discharges to the surface, trespassers and workers have the potential for exposure from seeps and outfall surface water.

The HHRA determined that the ELCR for future, on-site residents exposed to Group II groundwater via ingestion, dermal contact and inhalation could be as high as 2.24E-01 (Table 2-1), exceeding the acceptable risk level of 1.0E-06. The HHRA determined that the ELCR for trespassers exposed to seeps and the Outfall via ingestion, inhalation, and dermal contact could be as high as 5.18E-05 (Table 6-8, Appendix A), exceeding the acceptable risk level of 1.0E-06. The HHRA determined that the ELCR for construction workers exposed to Group II groundwater via ingestion and dermal contact could be as high as 4.88E-03 (Table 6-7, Appendix A), exceeding the acceptable risk level of 1.0E-06.

Due to the shallow depth to perched groundwater and relatively low yield, availability of municipal water supplies, and likely continued industrial use of the property, a future scenario under which on-property residential use of groundwater would occur is not anticipated. For this reason, no RAO to specifically address the risk from use of groundwater by future on-site residents is included in this SFS. Rather, RAOs to reduce unacceptable exposure to Group II groundwater focus on (1) reducing the concentrations in, and volume of contaminated groundwater on the EM Science property by reducing contact with contaminated material in source areas, (2) compliance with ARARs, and (3) limiting the pathways of likely exposure.

Therefore, the RAOs for Group II groundwater are:

- Reduce infiltration to minimize the volume of groundwater that contacts contaminated soil/fill in the Combined Middle West Ravine to prevent leaching
- Eliminate leachate/seeps and groundwater migration to off-property areas to comply with ORC Section 6111
- Prevent exposure to perched groundwater during excavation and/or construction activities to prevent an ELCR of >10-6 and HI >1

It is important to note that these RAOs, and risk upon which they are based, contribute to the need to reduce infiltration to minimize the volume of groundwater that contacts contaminated soil/fill in the Combined Middle West Ravine to prevent leaching, as discussed in Section 2.4.3.

2.4.7 Eastern Boundary Groundwater

The Group II groundwater that migrates to the eastern boundary of the property is considered potentially potable based upon its yield and depth below ground surface. The contaminants that constitute risk drivers for the eastern boundary groundwater are VOCs, generally the same VOCs that are migrating to the southern property boundary. The HHRA indicated that the future ELCR for ingestion and inhalation of contaminants (primarily VOCs) by residents in the vicinity of the eastern EM Science property boundary could be as high as 8.75E-03 (Table 2-1). This estimate is considered fairly conservative considering that the likelihood of the consumption of eastern boundary groundwater by residents is low primarily because the area is served by municipal water supplies. In addition, the risk estimate did not take into account long-term continuation of the French drain groundwater collection system. However, because the risk exceeds the 1.0E-06 ELCR acceptable risk defined in the NCP, the following RAO was developed for eastern boundary groundwater:

- Prevent migration of contaminants to the eastern property boundary to prevent an ELCR >10-6 and HI >1 by future off-property residents

2.5 PRELIMINARY REMEDIATION GOALS

The acceptable contaminant-specific exposure levels required to achieve the RAOs can be either a chemical-specific ARAR, or, in absence of such an ARAR (or when an ARAR is not sufficiently protective), a risk-based concentration derived from site-specific information and established exposure assumptions. These risk-based concentrations are known as preliminary remediation goals (PRGs). The NCP explains that "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure;" (40 CFR 300.430(e)(i)(A)(2)).

As discussed in Section 2.4 and shown in Tables 2-1 and 2-2, the HHRA indicated that various risk scenarios resulted in risk exceeding the 1E-06 threshold. Risk-based concentrations that would be required to reduce the risk to below the 1E-06 level were calculated in the RI and presented as PRGs in RAO TM 10, with the exception that PRGs were not developed for the RME off-site receptor scenario for emissions from soil/ fill, even though this exposure scenario resulted in the highest risk of the exposure scenarios evaluated for some parameters and areas (Areas 1, 2, and 4). There are no promulgated chemical-specific ARARs for soil, so the PRGs calculated and presented in RAO TM 10 were used in this

SFS as the acceptable exposure levels for the purposes of developing alternatives to meet the RAOs at the Site. Because several contaminants and pathways may contribute to the overall site risk, the relevant PRGs in RAO TM 10 are the lowest levels corresponding to the "multi-contaminant" 1E-06 risk scenario to ensure that the combined ELCR is below 1E-06 or the HI is less than 1.

Tables 2-5 and 2-6 provide a compilation of soil PRGs for the EM Science site that were presented in RAO TM 10 (Appendix C). The different exposure scenarios and EPCs used in the HHRA resulted in multiple PRGs for Area 3, Combined Middle West Ravine (Tables 2-4 through 2-10 in Appendix C). The creation of Table 2-5 condenses the various PRGs for Area 3 into a single format to allow for comparison between the various PRGs according to exposure pathway. To be conservative, the lowest PRG is assumed to apply to this SFS for the purposes of estimating volumes and surface areas applicable to remediation.

Table 2-6 includes the PRGs for pathways and associated SSPL constituents that resulted in risk that exceeded the thresholds determined for each soil/ fill area, with the exceptions of (1) risks associated with the RME off-site receptor and (2) risk-based PRGs for Area 5: East Ravine soil/fill. Risk-based PRGs associated with the RME off-site receptor scenario and exposure to constituents in Area 5 were excluded from the scope of RAO TM 10. Because the RME off-site receptor scenario resulted in unacceptable ELCR, development of risk-based remedial goals to address the RME off-site receptor pathway may be required for some constituents prior to final remedy selection. Likewise, the HHRA indicated unacceptable ELCR for exposure to Area 5: East Ravine soil/fill for multiple constituents and pathways (Tables 2-1 and 2-2). Development of risk-based remedial goals to address risks present in Area 5: East Ravine soil/fill may be required for some constituents prior to final remedy selection. However, the conservative nature of the scope of the remedial alternatives presented in this SFS is anticipated to address the risk associated with the RME off-site receptor and Area 5: East Ravine soil/fill even though PRGs specific to this pathway and portion of the site are not presented at this time.

PRGs for groundwater and surface water are presented in Table 2-7. Final remediation goals for soil and water will be determined in the remedy decision document based on the general goal to reduce total site risk to an overall ELCR of less than 10-6 and HI less than 1.

2.6 AREAS SUBJECT TO REMEDIATION

Table 2-8 provides a summary of the areas determined for each of the surface/ fill areas previously described in this section using the ELCR of 10-6 for multiple constituents as the basis for establishing the footprint for required remediation. The dimensions in Table 2-8 are used in subsequent sections of the SFS. The areas are based on information presented in RAO TM 10 and AA Report, TM 14. Because the area groupings in this SFS differ from those in RAO TM 10 and AA Report, TM 14, Table 2-8 also includes a summary of the sources and assumptions used to calculate the combined areas. These dimensions are approximate, and subject to change during Remedial Design (RD).

3.0 SCREENING AND IDENTIFICATION OF TECHNOLOGIES AND PROCESS OPTIONS

In the EM Science draft FS, remedial technologies and process options were gathered through a literature review of technical guidance documents, databases, and technical journals. The technologies and options gathered were for containment and/or treatment of contaminated soil, groundwater, and off-gases associated with remedial activities considered for the EM Science site. The screening process reduces the variety of possible process options for a given technology to a smaller, more manageable number of options that are considered for the various media. During the initial screening, information such as site geologic or hydrogeologic conditions, results of the three post-RI treatability studies, and contaminant type and concentration were used to eliminate various technologies and process options that do not appear to be technically feasible at the site. After this initial screening in the EM Science draft FS, the remaining remedial technologies and process options were considered potentially applicable to the site. The screening and evaluation procedures used are described in Section 3.1.

3.1 SCREENING AND EVALUATION OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

This section discusses evaluation and screening procedures used to determine remedial technologies and process options.

3.1.1 Evaluation Procedures

The evaluation of these remedial technologies and process options was based on three criteria: effectiveness, implementability and cost.

Effectiveness

Effectiveness consists of the following elements:

- Ability to protect human health and the environment
- Anticipated reductions in toxicity, mobility or volume through treatment
- Short-term impacts to human health and the environment during construction and implementation

- Long-term reliability of remedial methods
- Ability to address the estimated volumes of contaminated media at the site

Implementability

Implementability encompasses technical issues, administrative issues, and the availability of services, including the following:

- Ability to obtain agency approval and permits;
- Ability to construct and operate the process option;
- Availability (including capacity) of treatment, storage, and disposal (TSD) services; and,
- Availability of necessary equipment and skilled workers.

Cost

Costs include capital as well as operation and maintenance (O & M) costs. At the screening stage, costs are preliminary and relative and may be based on treatability studies, data from similar sites, engineering judgment, general costing guides, or technical guidance documents and literature. At this stage of the SFS, remedial technologies or process options are generally not screened out of consideration based on cost alone.

3.1.2 Screening Procedures

The remedial technologies and process options presented in the EM Science draft FS (Appendix D) were screened further for groundwater and fill/soil. These options are summarized in Tables 3-1 and 3-2 of this SFS and are discussed below. The screening was based on the information presented in the EM Science draft FS and general engineering judgment regarding effectiveness and implementability. Except for the no-action alternative, the actions that remain are those that are likely to achieve the RAOs and comply with ARARs for the site. At least one technology from each general response action is retained unless the general response action is either not effective or not implementable. The no-action alternative is carried through the SFS to serve as a baseline against which to compare the remaining alternatives.

Table 3-1 contains technologies and process options that were considered to potentially address groundwater contamination at the site. Table 3-2 contains technologies and process options that were considered to potentially address soil/fill contamination at the site. The shaded areas in the tables show technologies or options that are eliminated from further consideration in this SFS. Relying on the existing interim actions only does not achieve the RAOs for the site.

The vertical barrier options were eliminated because of their difficult implementation and inability to address all COPCs. Instead, surface control process options were retained as representative of the containment general response action because they are all effective and implementable.

3.2 IDENTIFICATION OF REMEDIAL ALTERNATIVES AND PROCESS OPTIONS

The following sections identify the results of the groundwater and soil alternatives screening process.

3.2.1 Groundwater Options

There are two general response actions for groundwater that involve treatment; 1) in-situ physical treatment and 2) ex-situ physical treatment. The in-situ physical treatment technologies have been screened from further consideration in favor of the ex-situ technologies because information reported by EM Science has indicated that in-situ technologies are inhibited by variable geologic site conditions and the types of contaminants present in site groundwater. These conditions create uncertainty as to the effectiveness of the in-situ technologies.

Ex-situ physical treatment technologies are generally reliable and use conventional technology. However, an ex-situ chemical treatment technology, chemical precipitation, has been eliminated because it may not treat all of the organic contaminants encountered at the site.

Two surface control technologies, grading and soil stabilization/vegetation, were presented in the EM Science draft FS and Appendix IV of the RAO TM 10 as potential technologies to manage and contain surface water run-off to augment groundwater response actions. Both grading and soil stabilization/vegetation have potential application at Areas 1 and 2, Mouth of the West Ravine, to prevent erosion of the fill material that exists within the ravine. The use of vegetative surface controls is not applicable in areas of the site where the RAO is to prevent contact between infiltration and contaminated soil/fill in Area 3, Combined Middle West Ravine.

Four discharge options for collected groundwater were retained from the EM Science draft FS and are presented in Table 3-1. Two discharge options, beneficial reuse and reinjection were eliminated from further consideration. Beneficial reuse was eliminated because additional on-site treatment may be required before the water can be used, subverting the low-impact, low-cost purpose of reusing the water. Reinjection was eliminated because it may be technically impossible to safely reinject water into the perched system beneath the Site without adversely affecting the existing groundwater regime.

A preliminary assessment of natural attenuation was conducted after the RI and was determined to produce variable results with respect to long-term remediation. Some reduction in contaminant concentrations was observed that might be attributable to biological and chemical degradation. However, uncertainties over the rates of degradation preclude reliance on natural attenuation as the sole groundwater remedy. The available information on site-specific natural attenuation was considered when developing the remedial alternatives presented in Section 4.0.

Construction of a permeable reactive barrier (PRB) was included as a component of the groundwater remedial alternatives presented in the EM Science draft FS. The PRB technology consists of a "wall" of permeable reactive material, typically granular, zero-valent iron. The wall is constructed below ground level and downgradient of a contaminated groundwater plume. As contaminated groundwater flows through the wall, certain contaminants react with the material and are immobilized or converted to more biodegradable, less toxic compounds.

PRB technology has been screened from further consideration for the groundwater at the EM Science site. Although choosing PRB technology would fulfill the statutory preference for treatment, research shows that iron PRBs are typically only effective at remediating chlorinated VOCs and some metals and would not effectively reduce, or have not been successfully demonstrated to reduce, other contaminants present in site groundwater such as benzene and 1,4-dioxane. Therefore, an iron PRB would have to be used in conjunction with other technologies to address all COCs, which may not be practical or feasible due to topographic and hydrogeologic factors and spatial constraints in the vicinity of the southern property boundary.

3.2.2 SOIL OPTIONS

Although presented separately in Table 3-2, the remedial technologies and process options for soil/fill must be integrated with groundwater options to complete a comprehensive alternative for addressing contamination at the EM Science site. Seven of the general response actions proposed in the EM Science draft FS are presented in Table 3-2. They are: no action, institutional controls, containment, ex situ treatment, excavation, natural attenuation and disposal. At least one representative technology or process option was retained for additional evaluation from each general response action. The other technologies or process options were eliminated because they were deemed ineffective or were difficult to implement. For example, in situ treatment and several ex-situ treatment technologies such as physical, chemical and biological treatment were eliminated because they were not effective for all site contaminants or because they were difficult to implement. Incineration and thermal desorption were retained to address the statutory preference for treatment and to represent the ex-situ response action even though they do not address the inorganic contaminants. These technologies would be combined with an excavation option and off-site thermal treatment of the soil/fill would occur at a permitted facility with disposal options for the residual inorganic contaminants.

For the same reasons discussed in reference to groundwater response actions above, natural attenuation was dropped as a response action for addressing soil contamination. While the natural attenuation study showed that existing biological and chemical conditions could result in natural attenuation, the variable results caused the response action to be eliminated.

The soil/fill options that remain involve:

- Institutional controls
- Containment
- Excavation and disposal

These response actions can be used in combination to address the risk levels present at the site while accounting for site conditions. For example, excavation of the soil/fill containing the highest level of contaminants or material likely to be encountered by receptors in areas such as the Middle West Ravine, can be combined with containment in areas that contain lower-level concentrations of contaminants or contaminants at significant depths below the surface. Finally, because containment is only effective as long as the integrity of the cover is maintained, institutional controls restricting land use in the area are necessary.

4.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section describes the remedial alternatives developed to address the RAOs established in Section 2. Remedial action alternatives are developed to achieve the following goals described in the NCP:

- Protection of human health and the environment
- Attainment of ARARs, unless there are grounds for a waiver
- Cost effectiveness
- Use of permanent solutions and alternate treatment or resource recovery technologies to the maximum extent practicable
- Satisfaction of the preference for treatment

To meet these goals, a range of alternatives was developed following the recommendations in the NCP (40 CFR 300.430(e)(3) for source control actions. The range of alternatives include:

- No action alternative
- One or more alternatives that involve little or no treatment but protect human health primarily by preventing or controlling exposure
- A treatment alternative that reduces the toxicity, mobility or volume of hazardous substances and eliminates the need for long-term monitoring

The NCP also recommends that for source control actions, one or more innovative treatment technologies be developed if those technologies offer the potential for comparable or superior performance or implementability, fewer or lesser adverse impacts, or lower costs for similar levels of performance than demonstrated treatment technologies. As described in Section 3, one innovative option, permeable reactive barrier technology, was evaluated for this site but was eliminated because the technology was unable (or unproven) to treat all the contaminants of concern and may not be readily implemented based upon current understanding of site conditions.

Remedial action alternatives were developed by combining screened technologies and process options from Section 3 to provide integrated solutions for remediation of contaminated soil, fill and groundwater at the site. Four remedial alternatives were developed from these remaining options and site-specific conditions. Because groundwater contamination in the perched zone is directly related to soil/fill contamination, each of the following alternatives was developed to address both soil and groundwater RAOs in order to be protective of human health and the environment.

Alternatives are typically evaluated, screened, and further refined to reduce the number of alternative and process options for detailed analysis. However, when circumstances limit the number of available options and the number of alternatives developed, it is not necessary to screen alternatives prior to the detailed analysis (EPA 1988). In order to streamline the analysis of alternatives, the alternatives developed in the EM Science draft FS have been reduced to the four alternatives presented below. This step is based on the technical information presented in the EM Science draft FS as well as engineering judgment regarding technologies and process options that have the highest likelihood of attaining the RAOs and complying with ARARs. The four alternatives are described below and are analyzed in detail in Section 5.0:

Alternative 1: No action, with discontinuation of interim measures

Alternative 2: Perimeter leachate collection with on-property treatment and off-property disposal, excavation and disposal of materials from soil/ fill Area 1 (off -property portion of the Mouth of the West Ravine), ARAR-compliant containment of on-property material in soil/ fill Areas 2, 3, 4 and 5 upon the existing grade, continuation of existing interim actions, and institutional controls

Alternative 3: Perimeter leachate collection with on-property treatment and off-property disposal, excavation and disposal of materials from soil/ fill Area 1, limited excavation and disposal of on-property materials from soil/fill Area 3 , ARAR-compliant containment of remaining on-property material in soil/fill areas upon a prepared grade (Area 3) and existing grade (Areas 2, 4, and 5), continuation of existing interim actions, and institutional controls

Alternative 4: Perimeter leachate collection with on-property treatment and off-property disposal, excavation and disposal of materials from soil/ fill Area 1, extensive excavation and disposal of on-property materials from soil/ fill Area 3, ARAR-compliant containment of remaining on-property material in soil/fill areas material upon a prepared grade (Area 3) and existing grade (Areas 2, 4, and 5), continuation of existing interim actions, and institutional controls

The common approach in Alternatives 2, 3, and 4 to managing on-property contaminated soil/fill is to use containment to meet the RAOs established in Section 2. In accordance with current Ohio EPA policy and practice, this SFS assumes that a solid waste cap in compliance with OAC 3745-27 is an appropriate and relevant requirement for contaminated soil/fill that remains at the site in Areas 2, 3, 4, and 5. Therefore, containment options must be ARAR-compliant. This assumption, while conservative, provides a consistent, upper bound interpretation, upon which the alternatives are structured. Currently, Ohio's solid waste rules specify a composite cap system designed for closure of sanitary landfills. The minimum design components of the composite cap system include a soil barrier or geosynthetic clay layer, a flexible membrane liner, a drainage layer, a frost protection layer, and a vegetative layer. At EM Science, it is recognized that site conditions differ than those at a sanitary landfill facility, and the conventional cap system design would be restrictive to end use of the property. Therefore, a design modification to allow alternative cap systems and covers that meet the intent of the performance standards of the solid waste rules while allowing continued use of the facility is contemplated in this SFS. Discussions between Ohio EPA's Southwest District office and the Central office indicate that a rule variance would be the appropriate vehicle to allow for alternative cap systems and containment covers.

4.1 ALTERNATIVE 1: NO ACTION

The no action alternative involves no remedial action and would leave contaminated soil and groundwater in place. In keeping with the definition of no action, existing interim actions such as operation of the sump and the French Drain would be assumed to be discontinued and any institutional controls currently in place, such as well construction restrictions, would be removed. No actions are taken to reduce the potential for exposure to contaminated media. Natural degradation of the contaminants in the soil and groundwater may occur under the no action alternative; however, there is no means to verify that the process is occurring. Because the no action alternative does not manage or reduce the risk associated with the site, the magnitude of residual risk remaining at the site would essentially be the same as the current risk at the site.

This alternative does not require remedial action, so it is readily implementable. There are no costs associated with the no action alternative other than those associated with any ongoing monitoring and five-year reviews.

In summary, this alternative does not meet the requirements of overall protection of human health and the environment. Instead, the no action alternative serves as a baseline for comparison with and evaluation of other alternatives.

4.2 ALTERNATIVE 2: PERIMETER LEACHATE COLLECTION AND ON-PROPERTY CONTAINMENT (EXISTING GRADE)

This alternative includes the following primary components in the designated site areas:

- Perimeter Leachate Collection – southern property boundary, assumed at top of slope
- Area 1: Off Property Mouth of the West Ravine: Excavation, Disposal, and Reconfiguration

- Area 2: On-Property Mouth of the West Ravine: Containment (ARAR-compliant cap built on existing grade)

- Area 3: Combined Middle West Ravine Containment (ARAR-compliant cap built on existing grade)

- Area 4: Upper West Ravine Containment (ARAR-compliant cover built on existing grade)

- Area 5: East Ravine Containment (ARAR-compliant cover built on existing grade)

- Institutional Controls

Figure 4-1 depicts the conceptual scope of Alternative 2. The following sections describe the purpose of each remedial component of Alternative 2 with respect to the RAOs. With the exception of Area 3, these components are also components of Alternatives 3 and 4. Instead of repeating the descriptions of these common components in the remaining alternatives discussion, these sections will be incorporated by reference in the description of Alternative 3, found in Section 4.3 and of Alternative 4, found in Section 4.4.

4.2.1 Perimeter Leachate Collection

The volume of contaminated groundwater would be reduced through a Perimeter Leachate Collection (PLC) system, consisting of new and existing ground water collection, transport, and treatment systems. This would incorporate the following specific actions:

- Construction and operation of a new sump, upgradient of the existing Sump-562 on EM Science property (On-property Sump); water collected in the On-Property Sump would be discharged to an on-site treatment facility

- Construction of a new collection system that will collect ground water in the southern portion of the Site and in the vicinity of Seep 562 in the Mouth of the West Ravine and convey it to the On-property Sump

- Continued operation and maintenance of the existing French drain ground water collection system in the eastern portion of the Site

- Pumping of ground water from the existing P6A gradient control well when ground water monitoring indicates it is necessary

- Discharge of all collected water to the City POTW after passage through an on-site water treatment plant. A new PTI/PTO permit or modification to the existing PTI/PTO permit will be required.

- Continuation of a site-wide groundwater and storm water management/monitoring program.

Section 4.2.2 describes the excavation and reconfiguration of soil/ fill Area 1 – off-property Mouth of the West Ravine area. This would include the removal of existing Sump-562 and construction of a new on-property sump, which would discharge collected water to an on-site treatment facility.

In the southern portion of the site, a new collection system will be constructed. The new system will include a series of deep French drains or selectively permeable materials. Due to Site topography, the required depth of installation and ultimate design will depend on the system location. These factors will be developed in the RD.

The alternatives described in this SFS are based on an on-property system that would extend along the southern property boundary, from the south end of the existing French drain, across the reconfigured Mouth of the West Ravine (see Section 4.2.2), to the vicinity of the western edge of Building 4 (see Figure 4-1). (Approximate dimensions and depths assumed to be required for this system are presented in EM Science 2002). This assumption, while conservative, provides a consistent, upper bound interpretation upon which the alternatives are structured; however, alternate locations for the PLC system may ultimately reduce the cost associated with this component of the remedial alternatives.

The system would be designed to capture VOC- and inorganic-contaminated groundwater posing an ELCR greater than 1.0 E-06 or HI greater than 1 that migrates through thin silt seams in the upper portion of the Lacustrine Unit in the southern portion of the site. The collected groundwater would be discharged into the on-property sump, which would then discharge the water to an on-site treatment facility, thus preventing discharge of contaminants to the Duck Creek watershed.

In the eastern portion of the site, the existing French drain would continue operation. Groundwater collected by this system would be discharged to an on-site treatment facility through the existing Middle and South Lift Stations. The French Drain currently does not intercept groundwater that is located in the deeper sand seams of the Upper Lacustrine Unit. Existing gradient control well P6A will be used to pump water from these sand seams to an on-site treatment facility if groundwater monitoring indicates this is necessary to prevent contamination from migrating off-property.

Groundwater collected by the existing French Drain and the new collection system would be pumped to an on-site water treatment facility, followed by disposal at the POTW. A new or modified PTI/PTO permit will likely be required. The discharge from the on-site treatment facility would be required to meet the pretreatment ARARs described in Section 2.3.1 prior to discharge to the POTW. Ex-situ treatment options that survived the screening process may be implemented at the on-site treatment facility. These options include air stripping and liquid phase carbon for treatment of organics (see Table 3-1). Additional ex situ treatment may be needed for treatment of inorganics. Use of these control technologies is consistent with the NCP preference for alternatives that minimize cross-media transfer of contaminants.

In addition, a site-wide groundwater and storm water management-monitoring program would be implemented to:

- Evaluate the efficacy of the PLC system;
- Monitor contaminant trends;
- Verify there are no significant increases in constituents of concern in monitoring wells along the southern and eastern property boundaries; and
- Verify the ongoing effectiveness of the existing storm water management program, including on-property surface water drainage controls.

The PLC system addresses the RAOs for Group II groundwater and Eastern Boundary groundwater, as described in Sections 2.4.6 and 2.4.7, respectively. The PLC system meets the RAOs by collecting and treating contaminated groundwater and disposing of the water off-site to prevent inhalation or ingestion exposures to current workers or future residents. The PLC also meets the ARARs described in Section 2.3.1 by preventing the discharge of contamination to waters of the state.

4.2.2 Area 1: Mouth of the West Ravine – Excavation and Reconfiguration

Area 1, the off-property portion of the Mouth of the West Ravine, is located near the southern property boundary, and terminates on ODOT property, adjacent to westbound SR 562. Under Alternatives 2, 3, and 4, the Mouth of the West Ravine would be excavated back to the property line and contaminated materials would be disposed of at an off-site landfill. The area would then be graded and a vegetative cover (non-ARAR compliant) would be constructed over the slope. The design of the reconfiguration of the Mouth of the West Ravine would be integrated with the design of the PLC system described in Section 4.2.1. Slope and cover specifications will be finalized during the RD. The estimated surface area of the off-property portion of the Mouth of the West Ravine is 8,610 sf, or 50 percent of the total area listed in Table 3-2 of RAO TM 10. Consistent with RAO TM 10, an average depth of 2 feet is assumed for the excavation resulting in 17,220 cf or 638 cy for offsite disposal. The actual dimensions of the excavation will be based on PRGs calculated for Area 1.

Excavation of the off-property Mouth of the West Ravine will address RAOs described in Section 2.4.1. Excavation will remove contaminated off-property material in order to comply with ORC 6111.04 (A)(1). Excavation will also mitigate risks in excess of 1.0E-6 to potential off-site receptors from exposure to contaminated soil or fill.

4.2.3 Area 2: On-Property Mouth of the West Ravine – ARAR-Compliant Containment

According to the RI, Area 2, the on-property portion of the Mouth of the West Ravine, contains a heterogeneous fill that includes a combination of soil, demolition debris, and buried containers and bottles of waste material (including off-specification chemical product). Under Alternatives 2, 3, and 4, the mixed waste and soil/fill of the on-property Mouth of the West Ravine would be contained with an ARAR-compliant cap. Preparation of the existing surface would be performed as necessary to construct a conventional multilayered cap system, however, no excavation or offsite disposal of material is anticipated.

The estimated surface area of the on-property portion of the Mouth of the West Ravine is 8,610 sf, or 50 percent of the total area listed in Table 3-2 of the RAO TM 10. ARAR-compliant containment of the on-property Mouth of the West Ravine will address the RAO described in Section 2.4.2.

4.2.4 Area 3: Combined Middle West Ravine – ARAR-Compliant Containment

Contaminated areas within Area 3: Combined Middle West Ravine (Middle West Ravine, areas south of Building 10, and south and east of Building 4) would also be covered with a conventional multilayered cap system as described for Area 2. The cap system in Area 3 would be constructed above the existing grade. As depicted in Figure 4-1, the Combined Middle West Ravine (Area 3) cover would be integrated with the Area 2 cover described in Section 4.2.3. The total estimated surface area for containment of the combined Middle West Ravine based on quantities presented in RAO TM 10 is approximately 88,259 sf.

The ARAR-compliant cap would be constructed over areas that present risks in excess of 1.0 E-6 or an HI greater than 1. The caps would be built upon the existing grade. This SFS assumes a conventional multilayer cap designed to address Ohio Solid Waste ARARs, resulting in a finished elevation approximately 4 feet above the current ground surface. Actual cap specifications and maintenance procedures will be compliant with ARARs and will be finalized in detail during the RD.

On-property containment would address RAOs for Area 3, soil/fill contamination described in Section 2.4.3, as well as Group II and Eastern Boundary groundwater described in Sections 2.4.6 and 2.4.7, respectively. Containment would prevent contact with contaminated soil/fill, vapors, and perched groundwater, as well as reduce surface water infiltration into the perched zone, which could further mobilize existing contamination.

4.2.5 Area 4: Upper West Ravine - ARAR-Compliant Containment, Existing Grade

Contaminated areas within Area 4: Upper West Ravine would be covered with conventional asphalt pavement built on the existing grade. A variance to Ohio's solid waste rules would be required to permit an asphalt cover that is ARAR-compliant. The total estimated surface area for containment of Area 4, Upper West Ravine based on quantities presented in RAO TM 10 is approximately 27,985 sf.

The pavement cover would be constructed and maintained in areas that present risks in excess of 1.0 E-6 or an HI greater than 1. The cover would be built upon the existing grade. Containment would prevent direct contact with contaminated soil/fill, the RAO for Area 4 described in Section 2.4.4.

4.2.6 Area 5: East Ravine - ARAR-Compliant Containment, Existing Grade

Contaminated areas within Area 5: East Ravine would be covered with conventional asphalt pavement built on the existing grade. A variance to Ohio's solid waste rules would be required to permit an asphalt cover that is ARAR-compliant. The total estimated surface area for containment of Area 5, East Ravine based on the description and site map referenced in AA TM 14 is approximately 57,000 sf.

The pavement cover would be constructed and maintained in areas that present risks in excess of 1.0 E-6 or an HI greater than 1. The cover would be built upon the existing grade. Containment would prevent direct contact with contaminated soil/fill, the RAO for Area 5 described in Section 2.4.5.

4.2.7 Institutional Controls

No deed restrictions or land use covenants are currently in place for the EM Science property. The risk assessment has identified unacceptable risks associated with land uses that go beyond the current industrial uses of the property. Examples of such activities include excavation for construction of basements or foundations, and installation of water supply wells. Institutional controls under this alternative would include land use controls that restrict the EM Science property to industrial use and prohibit construction of water supply wells or below-grade foundations. An "implementation plan" will be completed during the RD that describes how these land use restrictions will be implemented and enforced.

4.3 ALTERNATIVE 3: PERIMETER LEACHATE COLLECTION, LIMITED ON-PROPERTY EXCAVATION, DISPOSAL, AND ON-PROPERTY CONTAINMENT (PREPARED GRADE)

This alternative includes the following primary components in the designated site areas:

- Perimeter Leachate Collection – Southern property boundary, assumed at top of slope
- Area 1: Off-Property Mouth of the West Ravine Excavation, Disposal, and Reconfiguration
- Area 2: On-Property Mouth of the West Ravine Containment (ARAR-compliant cap built on prepared grade)
- Area 3: Combined Middle West Ravine - Limited Excavation and Disposal; On-Property Containment (ARAR-compliant alternative cap built on prepared grade)
- Area 4: Upper West Ravine Containment (ARAR-compliant cover built on existing grade)
- Area 5: East Ravine Containment (ARAR-compliant cover built on existing grade)
- Institutional Controls

Alternative 3 will include these components as described in Section 4.2, with the following addition. Area 3: Combined Middle West Ravine would first be excavated to a depth of 1 foot to allow construction of an alternate ARAR-compliant cap on a prepared sub base. The finished ARAR-compliant cover elevation would be flush with the existing grade, and constructed with materials designed for heavy truck traffic, facilitating continued use of the property. A variance to Ohio's solid waste rules would be required to permit an alternative cap system that is ARAR-compliant. Figure 4-2 depicts the conceptual scope of Alternative 3.

Although limited excavation would occur in this alternative, note that the RAO focuses on containment; therefore the need for excavation in Area 3, and the basis for the excavation depth would be solely related to the required cap thickness. The mixed fill (waste materials and soil) would be excavated to an estimated depth of 1 foot resulting in a volume (in-place) for off-property disposal of approximately 3,269 cy[1]. Excavation and off-property disposal of mixed waste materials and soil would be performed in areas of the site that present risks in excess of 1.0 E-6 or an HI greater than 1, which would be the same as those subject to Alternative 2; therefore the horizontal extent of excavation would be based on PRGs.

Alternative 3 would address RAOs for the areas of soil contamination described in Section 2.4.3, as well as Group II and Eastern Boundary groundwater described in Sections 2.4.6 and 2.4.7, respectively. Limited on-property excavation and containment combined with institutional controls would prevent contact with contaminated soil or fill vapors and perched groundwater, and also reduce surface water infiltration into the perched zone to further reduce movement of existing contamination.

4.4 ALTERNATIVE 4: PERIMETER LEACHATE COLLECTION, EXTENSIVE ON-PROPERTY EXCAVATION, DISPOSAL, AND ON-PROPERTY CONTAINMENT (PREPARED GRADE)

This alternative includes the following primary components in the designated site areas:

- Perimeter Leachate Collection – Southern property boundary, assumed at top of slope
- Area 1: Off-Property Mouth of the West Ravine Excavation, Disposal, and Reconfiguration
- Area 2: On-Property Mouth of the West Ravine Containment (ARAR-compliant cap built on prepared grade)
- Area 3: Combined Middle West Ravine – Extensive Excavation and Disposal; On-Property Containment (ARAR-compliant alternative cap built on prepared grade)
- Area 4: Upper West Ravine Containment (ARAR-compliant cover built on existing grade)
- Area 5: East Ravine Containment (ARAR-compliant cover built on existing grade)
- Institutional Controls

The components listed above were described in Sections 4.2 and 4.3, with the exception that Alternative 4 will include the following addition. Area 3, Combined Middle West Ravine, would be excavated to a

[1] (88,259 sf x 1 ft = 88,259 cubic ft; or 3,269 cy)

depth of 10 feet and disposed offsite. Area 3 would then be backfilled and covered with an ARAR-compliant alternative cap on a prepared sub base. The finished ARAR-compliant cap elevation would be flush with the current existing grade, and constructed with materials designed for heavy truck traffic, facilitating continued use of the property. A variance to Ohio's solid waste rules would be required to permit an alternative cap system that is ARAR-compliant. Figure 4-3 depicts the conceptual scope of Alternative 4.
Excavation and containment of mixed soil and waste materials and soil would be performed in Area 3 where conditions present an ELCR greater than 1.0 E-6 or a HI greater than 1. The horizontal extent of the Area 3 excavation would be the same in Alternatives 3 and 4, and would be based on PRGs. The purpose of the extensive excavation is primarily to address VOCs; therefore extensive excavation would be limited to Area 3. The depth of excavation in Area 3 would be set at 10 feet, as 10 feet is a reasonable maximum assumed depth for most construction activities anticipated to occur under the anticipated future site use scenario (commercial or industrial). The excavated mixed waste materials and soil from Areas 1 and 3 would result in a combined volume (in place) for off-property disposal of approximately 33,326 cy[2], as listed in Table 4-1.

Off-property excavation, and limited on-property excavation and containment would address RAOs for Areas 1, 2, 4, and 5 described in Sections 2.4.1, 2.4.2, 2.4.4, and 2.4.5, as well as Group II groundwater and seeps described in Sections 2.4.6. Excavation and containment combined with institutional controls would prevent contact with contaminated soil or fill vapors and perched groundwater.

The more extensive, deeper excavation of Alternative 4 addresses the RAOs for Area 3, the Combined West Ravine; and Eastern Property groundwater as described in Sections 2.4.3 and 2.4.7, respectively. This action meets the RAOs for soil by removing soils with significant risk levels to prevent inhalation, ingestion, or dermal exposures to on-site workers or future off-site residents. The deeper excavation meets RAOs for groundwater by removing primary sources of soil contamination to prevent further contamination of groundwater and to achieve groundwater cleanup levels in a shorter timeframe. ARARs will be achieved by proper disposal of the excavated material at an off-site facility, and containment of residual subsurface materials that pose a risk with an ELCR greater than 1E-6 or an HI greater than 1.

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[2] Area 1 volume = (8,610 sf x 2 ft)/27 = 638 cy; Area 3 volume = (88,259 sf x 10 ft)/27 = 32,688 cy; combined volume = 33,326 cy.

5.0 DETAILED ANALYSIS OF ALTERNATIVES

Alternatives described in Section 4 are evaluated in this chapter in detail to provide sufficient information to compare the alternatives, select an appropriate remedy, and demonstrate satisfaction of CERCLA remedy selection requirements in a decision document (DD). Although the evaluation has been simplified for the purpose of this SFS, the evaluation was performed in a manner consistent with the NCP and the guidance appended to the AOC. The detailed analysis of alternatives consists of the following components:

Evaluation criteria (Section 5.1)
Individual analysis of alternatives (Section 5.2)

5.1 EVALUATION CRITERIA

The detailed analysis of alternatives is based on the evaluation criteria specified by the NCP (40 CFR section 300.430(e)(9)(iii)) and guidance for conducting RIs and FSs under CERCLA (EPA 1988). The seven pertinent evaluation criteria from the NCP are described below. The "state acceptance" and "community acceptance " criteria are not considered in this SFS.

Overall protection of human health and the environment. This criterion describes the way that each alternative as a whole protects human health and the environment. The criterion focuses on a specific alternative's ability to achieve adequate protection and describes the way site risks passed through each pathway are eliminated, reduced, or controlled through treatment, engineering, or institutional controls. This evaluation also allows for consideration of any unacceptable short-term or cross-media impacts associated with each alternative. Other NCP criteria such as short and long-term effectiveness, permanence, and compliance with ARARs are considered in the overall assessment of protection.

Compliance with ARARs. This criterion evaluates each alternative's compliance with federal and state ARARs and "to be considered" requirements. If an ARAR variance is required, this criterion evaluates the approach taken to justify the variance. ARARs address location-specific, chemical-specific, and action-specific concerns.

Long-term effectiveness and permanence. This criterion addresses the risk remaining at the site after RAOs have been met. The primary focus of this evaluation criterion is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and untreated wastes. Factors considered include the magnitude of residual risks and adequacy and reliability of institutional controls.

Reduction of toxicity, mobility, or volume through treatment. This criterion addresses the statutory preference for remedial alternatives that employ treatment technologies for permanent and significant reduction of toxicity, mobility, or volume. This criterion focuses on (1) treatment processes and materials treated; (2) amount of hazardous materials that will be destroyed or treated; (3) degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction (or order of magnitude); (4) degree to which the treatment will be irreversible; (5) type and quantity of treatment residuals that will remain following treatment; and (6) ability of the alternative to satisfy the statutory preference for treatment as a principal element.

Short-term effectiveness. This criterion examines the effectiveness of each alternative in protecting human health and the environment during the construction and implementation period until protection is achieved. Four factors are considered when assessing the short-term effectiveness of an alternative: risks to the community during implementation of remedial actions, potential impacts to workers during remedial actions and the effectiveness and reliability of protective measures, environmental impacts of remedial actions and the effectiveness and reliability of mitigative measures, and time until protection is achieved.

Implementability. This criterion evaluates the technical and administrative feasibility of each alternative and the availability of various services and materials required during its implementation.

Cost. This criterion addresses capital costs, both direct and indirect; annual operation and maintenance (O&M) costs; accuracy of the cost estimate; present worth analysis; and cost-sensitivity analysis of alternatives. Guidelines for FS cost estimates are found in the EPA's *Guide to Developing and Documenting Cost Estimates During the Feasibility Study (EPA 2000).* According to the guidance, non-federal facilities receive a discount rate of 7 percent with no allowance for inflation. Capital and O&M cost estimates are order-of-magnitude level estimates and have an expected accuracy of minus 30 to plus 50 percent.

The first two criteria are categorized as threshold criteria; they relate directly to requirements that each remedial alternative must meet. If a given alternative does not satisfy both of these criteria, then it is not retained for further consideration beyond the individual analysis of alternatives. The next five are the primary balancing criteria upon which the selection of the remedy is based. State and community acceptance are known as modifying criteria. These criteria will be addressed in the DD after public comments have been received on the proposed plan. In the following sections, each alternative is described, assessed against the seven evaluation criteria, and comparatively analyzed to assess the relative performance of each alternative with respect to these criteria.

5.1.1 Special Considerations for Costs

Cost estimates for FSs are performed for comparative purposes and as such, are usually poor and inappropriate measures of absolute costs. Even when costs appear to be reasonable, a proper engineering cost opinion or, in the case of a design-build arrangement, detailed cost estimating must be performed prior to construction. Finally, the FS cost estimate should not be used as a sole basis for allocation or planning of financing or finance mechanisms.

Costs for the various remedial action components in this SFS were derived from four sources: the original draft FS (Payne Firm 2000), comments from EM Science (EM Science 2002), direct vendor quotes, and cost estimating software (Remedial Action Cost Engineering and Requirements [RACER] 2001 and 2003). All sources were evaluated for relevance and adjusted to 2003 dollars according to the Engineering News Record construction cost index. The discount rate was based on EPA guidance (EPA, 2000).

The cost estimate for each alternative is based on estimates of capital and operation and maintenance (O&M) costs. Capital costs consist of direct and indirect costs. Direct costs include the purchase of equipment, labor, and materials necessary to install components of the alternative. Indirect costs include those for engineering, financial, and other services, such as testing and monitoring. Annual O&M costs for each alternative include maintenance materials, labor, and auxiliary materials, as well as operating costs. Costs from The Payne Firm Draft FS are presented as Appendix E. Backup for the RACER cost analysis is presented as Appendix F.

It is assumed that periodic reviews would be conducted for all action-based alternatives, therefore, the review cost is not included as a remedial option cost because it has no comparative value in the detailed analysis of alternatives.

5.2 DETAILED ANALYSIS OF INDIVIDUAL ALTERNATIVES

This section describes in detail each of the four alternatives developed in Chapter 4 and evaluates each alternative against the seven evaluation criteria discussed in Section 5.1.

5.2.1 Alternative 1 - No Action

No remedial action would be taken under Alternative 1 and existing interim actions would be terminated. The physical condition of the contaminated soil and groundwater would remain unchanged. No institutional controls, containment, removal, or treatment would be implemented, and no other mitigating actions would be taken. Alternative 1 is retained throughout the FS process, consistent with the NCP, to provide a comparative baseline against which other alternatives can be evaluated.

5.2.1.1 Overall Protection of Human Health and the Environment

This alternative does not provide protection to human health and the environment because 1) exposure of on-site workers to VOCs, SVOCs, and inorganics in soil is not prevented, and 2) off-property migration of

VOC-contaminated groundwater is not prevented. This alternative does not achieve the RAOs described in Section 2.

5.2.1.2 Compliance with ARARs

This alternative will not comply with any of the ARARs identified in Section 2.

5.2.1.3 Long-Term Effectiveness and Permanence

This alternative would not provide long-term protection. Although the Site is expected to remain industrial, there are currently no controls in place to prevent development of the property or construction of water supply wells in the future. Exposures may occur during excavation activities, residential use or use of perched groundwater at the site.

5.2.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The no action alternative does not employ treatment and so does not meet this criterion of reducing the toxicity, mobility, or volume of contamination at the site. For this reason, the effectiveness of this alternative in reducing toxicity, mobility, or volume through treatment would be low.

5.2.1.5 Short-Term Effectiveness

Because the no action alternative involves no remedial action or construction, the alternative would not pose new health risks to the community, current occupants, workers or the environment in the short term. However, the no action alternative will not achieve protection of human health and the environment. Therefore, Alternative 1 cannot be considered to be effective in the short term.

5.2.1.6 Implementability

Because Alternative 1 involves no action, there are no technical or administrative difficulties involved with implementing this alternative. Therefore, implementability of this alternative is considered to be high.

5.2.1.7 Cost

No capital or O&M costs are associated with this alternative.

5.2.2 Alternative 2: Perimeter Leachate Collection and On-Property Containment (Existing Grade)

This alternative includes the following components:

- Perimeter Leachate Collection – Southern property boundary, assumed at top of slope
- Area 1: Off-Property Mouth of the West Ravine Excavation, Disposal, and Reconfiguration
- Area 2: On-Property Mouth of the West Ravine Containment (ARAR-compliant cap built on existing grade)
- Area 3: Combined Middle West RavineOn-Property Containment (ARAR-compliant cap built on existing grade)
- Area 4: Upper West Ravine Containment (ARAR compliant cover)
- Area 5: East Ravine Containment (ARAR compliant cover)
- Institutional Controls

This alternative is described in detail and evaluated in the following sections.

5.2.2.1 Overall Protection of Human Health and the Environment

The site risks to human health from the contaminated soil/fill and from contaminated groundwater currently exceed the NCP risk management threshold criteria for both media. The RI and risk assessment identified no unacceptable risks from this site to ecological receptors. This alternative will protect human health and the environment through collection and treatment of contaminated groundwater at the site, limited excavation of fill (waste material mixed with soil) and native soil in Area 1, and through containment of remaining contaminated on-site material that poses an ELCR greater tha greater than 1.0. Groundwater collected in the PLC system will be disposed under the environmental permits, specifically a new or modified PTI/PTO permit.

Alternative 2 vegetative cover

In addition, the off-property excavation and disposal component (Area 1) of this reme human health and the environment by removing contaminated material from the Moutl Ravine area and disposing of it in a permitted hazardous or solid waste landfill. The re contaminated on-property material in Areas 2 and 3 will be contained under a multilay compliant cap with a vegetative cover. ARAR-compliant asphalt pavement will be used to cover Areas 4 and 5 to prevent direct contact exposure. Finally, human health and the environment will be further protected by the imposition of land use controls on the EM Science site. The land use controls will restrict the future use of the EM Science site to only industrial use unless additional remediation takes place.

5.2.2.2 Compliance with ARARs

The primary ARARs for this site fall into three categories: surface and groundwater protection, solid and hazardous waste management, and air pollution control. This alternative complies with Section 6111 of the Ohio Revised Code by intercepting contaminated groundwater with the PLC before the groundwater migrates off-property and also before it is discharged to surface water (Duck Creek) by way of the 27- and 84-inch storm sewers. The treatment system following the PLC also complies with Section 6111 and the requirements of the PTI/PTO permit regulations because it will meet BATT/BADCT as defined by Ohio EPA. This requirement will be specific to the contaminants present in the extracted groundwater and BATT/BADCT concentrations will be identified by Ohio EPA in the final DD for the site.

This alternative will also comply with hazardous and solid waste ARARs. First, material excavated for off-site disposal will be characterized to determine if it is hazardous waste. If so, state hazardous waste requirements pertaining to generation, handling, treatment and disposal must be met (for example, OAC 3745-51). Excavated material determined to be hazardous waste will not be allowed to remain on-site and will be treated and disposed of in an appropriately permitted treatment, storage and disposal facility. If the excavated material for off-site disposal is identified as solid waste, requirements for generation, handling and disposal of solid waste, such as those found in OAC 3745-27 and OAC 3745-29, will be ARARs. To be conservative, the cost analysis conducted for the SFS assumes that all material excavated from the site will be classified as hazardous.

Containment by on-site capping to meet requirements for solid waste landfill caps (OAC 3745-27) is an assumed ARAR for Areas 2, 3, 4 and 5 in this SFS. The cost analysis for construction of an ARAR-compliant cap on Areas 2 and 3 under Alternative 2 is based on the assumption of multilayer construction with a minimum thickness of 4 feet. A conventional, multilayered cap with a vegetative cover is proposed for Area 2 under all three-action alternatives. The cap in Area 2 would be constructed upon the existing grade and be designed to tie-in with the PLC and Area 1 reconfiguration. Future use of Area 2 would be limited to protect the integrity of the vegetative cover. ARAR compliance with solid waste rules for Areas 4 and 5 would require a variance to permit conventional asphalt pavement.

Finally, Alternative 2 will use best management practices to provide dust suppression and eliminate fugitive VOC or particulate emissions in order to comply with state air pollution control regulations that apply to excavation and construction activities (OAC 3745-17-07 and OAC 3745-17-08). If the groundwater treatment system is projected to emit air pollutants in excess of those limits specified in state air pollution regulations for regulated point sources, the air pollution controls for the system will be designed to meet emission standards determined by Ohio EPA. In addition to complying with ARARs, use of these control technologies is consistent with the NCP preference for treatment that minimizes cross-media transfer of contaminants.

5.2.2.3 Long-Term Effectiveness and Permanence

One expectation of the NCP is for alternatives to treat or permanently remove the principal threat at the site. Alternative 2 would be moderately effective in the long term because a large portion of the on-site contaminated soil/fill (Areas 2, 3, 4, and 5) that presents a portion of the principal threat would remain contained onsite. However, containment can fulfill the NCP expectation if treatment or removals are demonstrated to be impracticable. Several in-situ treatment technologies were proved to be impracticable at the site through treatability studies conducted during the RI. Therefore, containment would fulfill this NCP expectation at the site. Containment is a proven and reliable technology that would reduce the possibility of human exposure to the contaminated materials. Long-term effectiveness would be thoroughly enhanced with a program of cap inspection and maintenance.

Excavation and disposal of material from Area 1 would be highly effective because the off-property contaminated material would be permanently removed. Excavation and disposal are proven and reliable technologies that would effectively remove the contaminated soil/fill and thus permanently reduce the possibility of human exposure to the contaminated materials at the site. Risk may remain from excavated materials disposed off-site, although it will likely be greatly reduced through assumed superior treatment or containment at the off-site permitted disposal facility.

The groundwater treatment element of this alternative fulfills the expectation in the NCP that treatment will be used to address the principal threats at a site (40 CFR 300.430(a)(1)(iii)(A)).

Because it will remain on site over the long-term, the contaminated material would act as a continuing source of groundwater contamination. Long-term operation and maintenance of the cap would be needed because residual concentrations would exceed unacceptable risk levels. Should the integrity of the cap be compromised, site risk levels could potentially return to the unacceptable levels that compelled this remedial action.

There are no existing restrictions to land use at the EM Science site so in order to maintain the protectiveness of the remedy; land use controls prohibiting any activity that would damage the cap or impair the PLC would be required to maintain protectiveness. For the off-property portion of the Mouth of the West Ravine, contaminated material would be excavated to PRGs so no land use controls will be needed to maintain long-term protectiveness.

5.2.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 would reduce the toxicity and volume of contaminants in the groundwater. The volume of contaminated groundwater will be reduced by collecting groundwater using the PLC and disposing off-site via the MSD, removing it from the hydrogeologic system. The toxicity of the contaminated groundwater will be reduced by treating collected water to remove contaminants prior to discharge to the MSD. The treatment would likely use an air stripper or other similar treatment unit to remove VOCs. Alternative 2 does not use treatment to address on-property contaminated soil/fill. The excavation and offsite disposal from the PLC trench and off-property Mouth of the West Ravine reduces the overall volume of contaminated soil/fill by approximately 1,400 cy (PLC trench = 726 cy, Area 1 = 638 cy). Off-site treatment of excavated material may be required prior to disposal in order to comply with the land disposal restrictions of RCRA.

5.2.2.5 Short-Term Effectiveness

This criterion examines the effectiveness of the alternative during construction and implementation of the remedy until the RAOs are met. In addition, the criterion considers the time to achieve protection.

Because Alternative 2 involves excavation (PLC, Area 1) and other construction activities (capping or covering of Areas 2, 3, 4, and 5), some short-term health risks may be created for site workers or the environment due to inhalation of fugitive emissions. The activity of greatest potential risk to workers is excavation. Risks to workers excavating contaminated soils can be easily mitigated by using dust suppression and VOC control practices during construction. On-site remedial workers would wear personal protective equipment during contaminated soil excavation activities. Potential risk to site workers could be reliably controlled with proper training, equipment and health and safety plans.

Transport of contaminated material from the site to landfills over public streets will also create short-term risks to the community due to fugitive emissions and the potential for spills from trucks. Based on a per truck capacity of 15 cy, an estimated 100 truck loads would be transported from the site to the permitted landfill. Again, established transport practices such as truck covers can be used to minimize the short-term risks.

Engineering controls would be used to minimize any impacts to the environment. Surface drainage controls and appropriate equipment decontamination procedures would be used to prevent transport of contaminated soil to uncontaminated areas.

About 6 months would be required to mobilize necessary equipment, excavate the contaminated soil, transport the soil and debris to an appropriately permitted landfill, construct the PLC system, construct the ARAR-compliant cap, restore the site, and demobilize. An additional 12- to 18-month period would be needed to conduct pre-design studies, prepare the remedial design (including all associated plans), and consult with appropriate agencies. Because exposure to contaminated soil would potentially continue until the on-property and off-property excavated material has been disposed off-site, protection would not be achieved for 2 years.

Alternative 2 would, therefore, be effective in the short term.

5.2.2.6 Implementability

The Alternative 2 soil containment component is easily implementable because construction of a multilayered, ARAR-compliant cap with a vegetative cover involves techniques, equipment, and procedures that are well proven and reliable. For the excavation and regrading of the Area 1: Mouth of the West Ravine, contractor, equipment, and transport companies skilled in hazardous soil removal are readily available as is disposal capacity for the contaminated soil/fill.

Installation of the PLC uses established construction techniques. However, construction logistics may be complicated by the need to integrate the design and sequence construction with the reconfiguration of the Mouth of the West Ravine and by the system's location relative to (1) the slope at the south property boundary; (2) SR 562; and (3) the railroad overpass near the southeastern property corner. Permits from local agencies should be readily available for temporary air permits for excavation and new or modified discharge permits for the waste stream from the groundwater treatment system.

5.2.2.7 Cost

The net present value of capital and operation and maintenance (O & M) costs associated with Alternative 2 is estimated to be $6.9 million. These costs include capital costs for construction of the PLC system, containment of on-site contaminated soil/fill as well as excavation and disposal of contaminated material excavated from the Mouth of the West Ravine. The cost for environmental monitoring and obtaining permits from local agencies is also included. The total capital cost estimate is $4,074,000. Annual O&M costs are estimated to be $230,000 per year. Table 5-1 presents a detailed breakdown of these costs.

5.2.3 Alternative 3 – Perimeter Leachate Collection, Limited On-Property Excavation, Disposal, and On-Property Containment (Prepared Grade)

Alternative 3 includes the following components:

- Perimeter Leachate Collection – Southern property boundary, assumed at top of slope
- Area 1: Off-Property Mouth of the West Ravine Excavation, Disposal, and Reconfiguration
- Area 2: On-Property Mouth of the West Ravine Containment (ARAR-compliant cap built on existing grade)
- Area 3: Combined Middle West Ravine Limited Excavation (1 ft), Disposal, and On-Property Containment (alternative ARAR-compliant cap built on prepared grade):
- Area 4: Upper West Ravine Containment (ARAR compliant cover)
- Area 5: East Ravine Containment (ARAR compliant cover)
- Institutional Controls

The type of alternative cap envisioned for Area 3 is a modified asphaltic concrete cap. For the purposes of this SFS, assumptions regarding technical specifications, performance, and cost are based on the MatCon™ (Modified Asphalt Technology for Waste Containment) technology. MatCon™ asphalt uses a proprietary polymer binder, selected aggregate, and specialized mix design under patent by W Construction Company (Wilder), Everett, Washington. The use of MatCon™ for waste contai part of an ongoing study under the U.S. EPA Superfund Innovative Technology Evaluation (SI program. Vendor-supplied information (Wilder Construction 2003) and preliminary data from t study (Carson et al 2003) indicate that a modified asphaltic concrete system would be a feasible alternative cap that would meet performance standards, satisfy ARARs, and be suitable for use w active, industrial plant setting. The alternative cap for Area 3 would be designed to be flush with existing plant grade, requiring a limited excavation to prepare an adequate subbase. Based on preliminary

Alternative 3 asphalt / concrete cap

vendor recommendations, an excavation of 1 foot is assumed, allowing for an 8-inch subbase followed by a 4-inch layer of modified asphaltic concrete.

This alternative is described in detail and evaluated in the following sections.

5.2.3.1 Overall Protection of Human Health and the Environment

The site risks to human health from the contaminated soil/fill and from contaminated groundwater currently exceed the NCP risk management threshold criteria for both media. The RI and risk assessment identified no unacceptable risks from this site to ecological receptors. This alternative will protect human health and the environment through collection and treatment of contaminated groundwater at the site, limited excavation of fill (waste material mixed with soil) and native soil where applicable, and through ARAR-compliant containment of remaining contaminated on-site material that poses an ELCR greater than 1.0E-6 or an HI greater than 1.0. Groundwater collected in the PLC system will be disposed under the restrictions of environmental permits, specifically a new or modified PTI/PTO permit.

In addition, the off and on-property excavation and disposal component (Area 1, PLC trench, and upper 12 inches of Area 3) of this remedy will protect human health and the environment by removing contaminated material from the Mouth of the West Ravine and Combined Middle West Ravine area and disposing of it in a permitted hazardous or solid waste landfill. The remaining contaminated on-property material will be contained under a multilayered, ARAR-compliant cap with vegetative cover (Area 2) and ARAR-compliant alternative cap (Area 3). ARAR-compliant conventional asphalt pavement will be used to cover Areas 4 and 5 to prevent direct contact exposure. Because this alternative scenario is based on the finish elevation of an alternative cap flush with existing plant grade in Area 3, material must be removed from Area 3 to allow for the construction of a cap that meets the technical requirements of solid waste ARARs and is capable of supporting traffic. Therefore, approximately 4,600[1] cy of contaminated soil/fill will be permanently removed from the site.

Modified asphaltic concrete caps been shown to be protective containment alternatives at several hazardous and non-hazardous waste facilities including the Tri-County Landfill (TCL) Superfund Site in Elgin, Illinois, and Dover Air Force Base (DAFB) site in Dover, Delaware. States that have approved the use of modified asphaltic concrete caps for landfill covers include California, Colorado, Delaware, Florida, Illinois, Kentucky, New Mexico, Texas, and Washington. The impervious character of such caps functions as an effective hydraulic barrier to prevent leachate production.

Finally, human health and the environment will be further protected by the imposition of land use controls on the EM Science site. The land use controls will restrict the future use of the EM Science site to industrial use only unless additional remediation takes place.

5.2.3.2 Compliance with ARARs

The primary ARARs for this site fall into three categories: surface and groundwater protection, solid and hazardous waste management, and air pollution control. This alternative complies with Section 6111 of the Ohio Revised Code by intercepting contaminated groundwater with the PLC before the groundwater moves off-property. The treatment system following the PLC also complies with Section 6111 and the requirements of the PTI/PTO permit regulations because it will meet BATT/BADCT as defined by Ohio EPA. This requirement will be specific to the contaminants present in the extracted groundwater and BATT/BADCT concentrations will be identified by Ohio EPA in the final DD for the site.

This alternative will also comply with hazardous and solid waste ARARs. First, excavated material for off-site disposal will be characterized to determine if it is hazardous waste. If so, state hazardous waste requirements pertaining to generation, handling, treatment and disposal must be met (for example, OAC 3745-51). Excavated material determined to be hazardous waste will not be allowed to remain on-site and will be treated and disposed of in an appropriately permitted treatment, storage and disposal facility. If the material excavated for off-site disposal is identified as solid waste, requirements for generation, handling and disposal of solid waste, such as those found in OAC 3745-27 and OAC 3745-29, will be ARARs. To be conservative, the cost analysis conducted for the SFS assumes that all material excavated from the site will be classified as hazardous.

Containment by on-site capping to meet requirements for solid waste landfill caps (OAC 3745-27) is an assumed ARAR for Areas 2, 3, 4 and 5 in this SFS. A conventional, multilayered cap with a vegetative cover is proposed for Area 2 under all three-action alternatives. The cap in Area 2 would be constructed upon the existing grade and be designed to tie-in with the PLC and Area 1 reconfiguration. Future use of Area 2 would be limited to protect the integrity of the vegetative cover. ARAR compliance with solid waste rules for Areas 4 and 5 would require a variance to permit conventional asphalt pavement.

[1] Area 1 volume = 638 cy; Area 3 volume = 3,269 cy ([88,259 sf x 1 ft]/27); PLC trench volume = 726 cy.

The alternative cap for Area 3 would conform to ARARs by meeting the performance intent of a conventional, multilayered cap in protecting human health and the environment. Data reported by EPA indicate that modified asphaltic concrete caps can be constructed with permeability of less than 10-7 cm/sec (Carson 2003). Ohio EPA has indicated that the use of modified asphaltic concrete in lieu of a conventional, multilayered cap could be approved with an administrative variance.

Finally, Alternative 3 will use best management practices to provide dust suppression and eliminate fugitive VOC or particulate emissions in order to comply with state air pollution control regulations that apply to excavation and construction activities (OAC 3745-17-07 and OAC 3745-17-08). If the groundwater treatment system is projected to emit air pollutants in excess of those limits specified in state air pollution regulations for regulated point sources, the air pollution controls for the system will be designed to meet emission standards determined by Ohio EPA. In addition to complying with ARARs, use of these control technologies is consistent with the NCP preference for treatment that minimizes cross-media transfer of contaminants.

5.2.3.3 Long-Term Effectiveness and Permanence

One expectation of the NCP is for alternatives to treat or permanently remove the principal threat at the site. Alternative 3 would be moderately effective in the long term because a large portion of the onsite contaminated soil/fill (Areas 2, 3, 4, and 5) that present a portion of the principal threat would remain contained onsite. The difference between Alternatives 2 and 3 is the removal of additional mixed waste material and contaminated soil to allow the construction of a cap over Area 3 that is capable of supporting heavy truck traffic, flush with the existing plant grade. The removal of contaminated material is highly effective in the long term because of the permanent nature of excavation and offsite disposal to reduce the principal threats posed by the site. Excavation and disposal are proven and reliable technologies that would effectively remove the contaminated soil/fill and thus permanently reduce the possibility of human exposure to the contaminated materials at the site. Risk may remain from excavated materials disposed off-site, although it will likely be greatly reduced through assumed superior treatment or containment at the off-site permitted disposal facility.

The remaining on-site contaminated soil/fill (Areas 2, 3, 4, and 5) that presents a portion of the principal threat would remain onsite. However, containment can fulfill the NCP expectation if treatment or removals are demonstrated to be impracticable. Several in-situ treatment technologies were proved to be impracticable at the site through treatability studies conducted during the RI. Therefore, containment would fulfill this NCP expectation at the site. Excavation (4,600 cy) and disposal, combined with containment of contaminated soil or fill on site, are proven and reliable technologies that would reduce the possibility of human exposure to the contaminated materials at the site.

Long-term effectiveness would be thoroughly enhanced with a program of inspection and maintenance of the ARAR-compliant caps in Areas 2 and 3 and the covers in Areas 4 and 5. The need for an inspection and maintenance program for the Area 3 cap would be greater under Alternative 3 than under Alternative 2 because of the potential continued industrial use of the site and associated heavy truck traffic. However, the placement of modified asphaltic concrete at the surface would also facilitate easier repair and maintenance of the cap system compared to a multilayered cap with a vegetative cover. Preliminary data reported by EPA from the SITE program indicates that modified asphaltic concrete caps require limited maintenance and provide long-term effectiveness. Wilder installed its first MatCon™ cap in 1989 and claims that the cover has maintained a 10-8 cm/sec permeability in spite of heavy equipment operation over the covered area.

The groundwater treatment element of this alternative fulfills the expectation in the NCP that treatment will be used to address the principal threats at a site (40 CFR 300.430(a)(1)(iii)(A)).

The excavated material would no longer act as a continuing source of groundwater contamination. However, because contaminated material will remain on site over the long-term, a source for continued groundwater contamination would exist. Long-term operation and maintenance of the cap would be needed because residual concentrations would exceed unacceptable risk levels. Should the integrity of the cap be compromised, site risk levels could potentially return to the unacceptable levels that compelled this remedial action.

There are no existing restrictions to land use at the EM Science site so in order to maintain the protectiveness of the remedy; land use controls prohibiting any activity that would damage the cap or impair the PLC would be required to maintain protectiveness. For the off-property portion of the Mouth of the West Ravine, contaminated material would be excavated to PRGs so no land use controls will be needed to maintain long-term protectiveness.

5.2.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 would reduce the toxicity and volume of contaminants in the groundwater by collecting contaminated groundwater and directing the collected water through a treatment system prior to discharge to the MSD. The treatment would likely use an air stripper or other similar treatment unit to remove

VOCs. Alternative 3 does not use treatment to address on-property contaminated soil/fill. However, the excavation and offsite disposal reduces the overall volume of contaminated soil/fill at the site by about 4,600 cy. Off-site treatment of excavated material may be required prior to disposal in order to comply with the land disposal restrictions of RCRA. The removal of contaminated soil/fill would reduce the amount of source material leaching to groundwater.

5.2.3.5 Short-Term Effectiveness

This criterion examines the effectiveness of the alternative during construction and implementation of the remedy until the RAOs are met. In addition, the criterion considers the time to achieve protection.

Because Alternative 3 involves excavation (PLC trench, Area 1, and Area 3) and other construction activities (capping of Areas 2, 3, 4, and 5), some short-term health risks may be created for site workers or the environment due to inhalation of fugitive emissions. The activity of greatest potential risk to workers is excavation. Risks to workers excavating contaminated soils can be easily mitigated by using dust suppression and VOC control practices during construction. On-site remedial workers would wear personal protective equipment during contaminated soil excavation activities. Potential risk to site workers could be reliably controlled with proper training, equipment and health and safety plans.

Transport of contaminated material from the site to landfills over public streets will also create short-term risks to the community due to fugitive emissions and spills from trucks. Based on a per truck capacity of 15 cy, an estimated 300 truck loads would be transported from the site to the permitted landfill. Again, established transport practices such as truck covers can be used to minimize the short-term risks.

Engineering controls would be used to minimize any impacts to the environment. Surface drainage controls and appropriate equipment decontamination procedures would be used to prevent transport of contaminated soil to uncontaminated areas.

About 4 months would be required to mobilize necessary equipment, excavate the contaminated soil, transport the soil to an appropriately permitted landfill, construct the PLC system, construct the ARAR-compliant caps, restore the site, and demobilize. The application rate of modified asphaltic concrete is similar to that of conventional asphalt pavement and significantly faster than constructing a multilayered cap. An additional 12- to 18-month period would be needed to conduct pre-design studies, prepare the remedial design (including all associated plans), and consult with appropriate agencies. Because exposure to contaminated soil would potentially continue until the on-property and off-property excavated material has been disposed off-site, protection would not be achieved for 1.5 to 2 years.

Alternative 3 would be slightly more effective than Alternative 2 in the short term.

5.2.3.6 Implementability

The Alternative 3 soil containment component is easily implementable because construction of both a conventional multilayered ARAR-compliant cap and a modified asphaltic cap involves techniques, equipment, and procedures that are well proven and reliable. For the excavation and regrading of Area 1 and excavation of Area 3 in preparation for cap construction, contractor, equipment, and transport companies skilled in hazardous soil removal are readily available as is disposal capacity for the contaminated soil/fill. The construction of a modified asphaltic concrete cap would involve a local asphalt batch plant and local paving contractor.

Installation of the PLC uses established construction techniques. However, as described in Section 5.2.2.6, construction logistics may be complicated by activities associated with the reconfiguration of the Mouth of the West Ravine, site topography and proximity to public roads and railroads. Permits from local agencies should be readily available for temporary air permits for excavation and new or modified discharge permits for the waste stream from the groundwater treatment system.

5.2.3.7 Cost

The net present value of capital and operation and maintenance (O & M) costs associated with Alternative 3 is estimated to be $7.3 million. These costs include capital costs for construction of the PLC system, excavation and disposal of contaminated material from all Areas (PLC, Area 1 and the upper 12 inches of Area 3), and containment of remaining on-site contaminated soil/fill. The cost for environmental monitoring and obtaining permits from local agencies is also included. The total capital cost estimate is $4,594,000. Annual O&M costs are estimated to be $219,000 per year. Table 5-2 presents a detailed breakdown of these costs.

5.2.4 Alternative 4 – Perimeter Leachate Collection and Extensive On-Property Excavation and On-Property Containment (Prepared Grade)

This alternative includes the following components:

- Perimeter Leachate Collection – Southern property boundary, assumed at top of slope

- Area 1: Off-Property Mouth of the West Ravine Excavation, Disposal, and Reconfiguration

- Area 2: On-Property Mouth of the West Ravine Containment (ARAR-compliant cap built on existing grade)
- Area 3: Combined Middle West Ravine Extensive Excavation (10 feet) Disposal and On-Property Containment (alternative ARAR-compliant cap built on prepared grade)
- Area 4: Upper West Ravine Containment (ARAR compliant cover)
- Area 5: East Ravine Containment (ARAR compliant cover)
- Institutional Controls

The only difference between Alternatives 3 and 4 is the additional excavation and disposal of materials to a depth of 10 feet in Area 3. The alternative cap system in Alternative 4 is the same as Alternative 3, a modified asphaltic concrete cap.

This alternative is described in detail and evaluated in the following sections.

5.2.4.1 Overall Protection of Human Health and the Environment

The site risks to human health from the contaminated soil/fill and from contaminated groundwater currently exceed the NCP risk management threshold criteria for both media. The RI and risk assessment identified no unacceptable risks from this site to ecological receptors. This alternative will protect human health and the environment through collection and treatment of contaminated groundwater at the site, extensive excavation of mixed waste material and soil, and through ARAR-compliant containment of remaining contaminated on-site material that poses an ELCR greater than 1.0E-6 or an HI greater than 1.0. Groundwater collected in the PLC system will be disposed under the restrictions of environmental permits, specifically a new or modified PTI/PTO permit.

Extensive excavation and disposal will be conducted in Area 3 (Combined Middle West Ravine) to remove fill (mixed waste and soil) and native soils (where applicable) to a depth of 10 feet. In add...
the off-property excavation and disposal component (Area 1) of this remedy will p...
and the environment by removing contaminated material from the Mouth of the W...
disposing of it in a permitted hazardous or solid waste landfill. The remaining co...
material will be contained under a multilayered, ARAR-compliant cap with vegetat...
ARAR-compliant conventional pavement (Areas 4 and 5). As in Alternative 3, this a...
based on the finish elevation of an alternative cap flush with existing plant grade in A...
the construction of a cap that meets the technical requirements of solid waste ARARs a...
supporting heavy truck traffic. However, a larger volume of material will be excavated ...ea 3 to

Alternative 4
excavation
Vegetative cover

provide additional permanence to the remedy. Therefore, with the additional excavation from Area 3, a significant volume, approximately 34,000[3] cy of contaminated soil/fill, will be permanently removed from the site. Finally, human health and the environment will be further protected by the imposition of land use controls on the EM Science site. The land use controls will restrict the future use of the EM Science site to industrial use only unless additional remediation takes place.

5.2.4.2 Compliance with ARARs

The primary ARARs for this site fall into three categories: surface and groundwater protection, solid and hazardous waste management, and air pollution control. This alternative complies with Section 6111 of the Ohio Revised Code by intercepting contaminated groundwater with the PLC before the groundwater moves off-property. The treatment system following the PLC also complies with Section 6111 and the requirements of the PTI/PTO permit regulations because it will meet BATT/BADCT as defined by Ohio EPA. This requirement will be specific to the contaminants present in the extracted groundwater and BATT/BADCT concentrations will be identified by Ohio EPA in the final DD for the site.

This alternative will also comply with hazardous and solid waste ARARs. First, excavated material for off-site disposal will be characterized to determine if it is hazardous waste. If so, state hazardous waste requirements pertaining to generation, handling, treatment and disposal must be met (for example, OAC 3745-51). Excavated material determined to be hazardous waste will not be allowed to remain on-site and will be treated and disposed of in an appropriately permitted treatment, storage and disposal facility. If the excavated material for off-site disposal is identified as solid waste, requirements for generation, handling and disposal of solid waste, such as those found in OAC 3745-27 and OAC 3745-29, will be ARARs. To be conservative, the cost analysis conducted for the SFS assumes that all material excavated from the site will be classified as hazardous.

Containment by on-site capping to meet requirements for solid waste landfill caps (OAC 3745-27) is an assumed ARAR for Areas 2 3, 4 and 5 in this SFS. A conventional, multilayered cap with a vegetative cover is proposed for Area 2 under all three-action alternatives. The cap in Area 2 would be constructed upon the existing grade and be designed to tie-in with the PLC and Area 1 reconfiguration. Future use of Area 2 would be limited to protect the integrity of the vegetative cover. ARAR compliance with solid waste rules for Areas 4 and 5 would require a variance to permit conventional asphalt pavement.

[3] Area 1 volume = 638 cy; Area 3 volume = ([88,259 sf x 10 ft]/27) = 32,689 cy; PLC trench volume = 726 cy.

The alternative cap for Area 3 would conform to ARARs by meeting the performance intent of a conventional, multilayered cap in protecting human health and the environment. Data reported by EPA indicate that modified asphaltic concrete can be constructed with permeability less than 10-7 cm/sec. Ohio EPA has indicated that the use of modified asphaltic concrete in lieu of a conventional, multilayered cap could be approved with an administrative variance.

Finally, Alternative 4 will use best management practices to provide dust suppression and eliminate fugitive VOC or particulate emissions in order to comply with state air pollution control regulations that apply to excavation and construction activities (OAC 3745-17-07 and OAC 3745-17-08). If the groundwater treatment system is projected to emit air pollutants in excess of those limits specified in state air pollution regulations for regulated point sources, the air pollution controls for the system will be designed to meet emission standards determined by Ohio EPA. In addition to complying with ARARs, use of these control technologies is consistent with the NCP preference for treatment that minimizes cross-media transfer of contaminants.

5.2.4.3 Long-Term Effectiveness and Permanence

The difference between Alternatives 3 and 4 is the removal of roughly an additional 30,000 cy of mixed waste material and contaminated soil from Area 3. The extensive excavation included in Alternative 4 will improve the permanence and long-term effectiveness of the remedy. The removal of such a large volume of contaminated material is highly effective in the long term because of the permanent nature of excavation and offsite disposal to reduce the principal threats posed by the site. Excavation and disposal are proven and reliable technologies that would effectively remove the contaminated soil/fill and thus permanently reduce the possibility of human exposure to the contaminated materials at the site. Risk may remain from excavated materials disposed off-site, although it will be greatly reduced through assumed superior treatment or containment at the off-site permitted disposal facility.

The remaining on-site contaminated soil/fill (Areas 2, 3, 4, and 5) that presents a portion of the principal threat would still remain onsite but be contained. Containment can fulfill the NCP expectation regarding treating or permanently removing the principal threats if treatment or removals are demonstrated to be impractical. Several in-situ treatment technologies were proved to be impracticable at the site through treatability studies conducted during the RI. Therefore containment would fulfill the NCP expectation at the site. Excavation (34,000 cy) and disposal, combined with containment of contaminated soil or fill on site, are proven and reliable technologies that would reduce the possibility of human exposure to the contaminated materials.

Long-term effectiveness would be thoroughly enhanced with a program of inspection and maintenance of the ARAR-compliant caps in Areas 2 and 3 and the covers in Areas 4 and 5. The need for an inspection and maintenance program for the Area 3 cap would be greater under Alternative 4 than Alternative 2 because of the potential continued industrial use of the site and associated heavy truck traffic. However, the placement of modified asphaltic concrete at the surface would also facilitate easier repair and maintenance of the cap system compared to a multilayered cap with a vegetative cover. Preliminary data reported by EPA from the SITE program indicates that modified asphaltic concrete caps require limited maintenance and provide long-term effectiveness. Wilder installed its first MatCon™ cap in 1989 and claims that the cover has maintained a 10-8 cm/sec permeability in spite of heavy equipment operation over the covered area.

The groundwater treatment element of this alternative fulfills the expectation in the NCP that treatment will be used to address the principal threats at a site (40 CFR 300.430(a)(1)(iii)(A)).

Alternative 4 would be an improvement over Alternative 3 because a large portion of the source of highly contaminated material from Area 3 would no longer act as a continuing source of groundwater contamination. However, because deeper contaminated material will remain on site over the long-term, a source for continued groundwater contamination would exist. Long-term O&M of the cap would be needed because residual concentrations would exceed unacceptable risk levels. Should the integrity of the cap be compromised, site risk levels could potentially return to the unacceptable levels that compelled this remedial action.

There are no existing restrictions to land use at the EM Science site so in order to maintain the protectiveness of the remedy, land use controls prohibiting any activity that would damage the cap or impair the PLC would be required to maintain protectiveness. For the off-property portion of the Mouth of the West Ravine, contaminated material will be excavated to PRGs so no land use controls will be needed to maintain long-term protectiveness.

5.2.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 would reduce the toxicity and volume of contaminants in the groundwater by collecting contaminated groundwater and directing the collected water through a treatment system prior to discharge to the MSD. The treatment would likely use an air stripper or other similar treatment unit to remove

VOCs. Alternative 4 does not use treatment to address on-property contaminated soil/fill. However, the excavation and offsite disposal significantly reduces the overall volume of contaminated soil/fill from the site by about 34,000 cy (Area 1 = 638 cy; Area 3 = 32,689 cy, and PLC trench = 726). Off-site treatment of excavated material may be required prior to disposal in order to comply with the land disposal restrictions of RCRA. The removal of a large volume of contaminated soil/fill would significantly reduce the amount of source material leaching to groundwater.

5.2.4.5 Short-Term Effectiveness

This criterion examines the effectiveness of the alternative during construction and implementation of the remedy until the RAOs are met. In addition, the criterion considers the time to achieve protection.

Because Alternative 4 involves deep excavation in Area 3 and other construction activities (capping of Areas 2, 3, 4, and 5), some short-term health risks may be created for site workers or the environment due to inhalation of fugitive emissions. The activity of greatest potential risk to workers is excavation. Risks to workers excavating contaminated soils can be easily mitigated by using dust suppression and VOC control practices during construction. On-site remedial workers would wear personal protective equipment during contaminated soil excavation activities. Potential risk to site workers could be reliably controlled with proper equipment and health and safety plans.

Transport of contaminated material from the site to landfills over public streets will also create short-term risks to the community due to fugitive emissions and spills from trucks. Based on a per truck capacity of 15 cy, an estimated 2,300 truck loads would be transported from the site to the permitted landfill. Again, established transport practices such as truck covers can be used to minimize the short-term risks.

Engineering controls would be used to minimize any impacts to the environment. Surface drainage controls and appropriate equipment decontamination procedures would be used to prevent transport of contaminated soil to uncontaminated areas.

About 6 months would be required to mobilize necessary equipment, excavate the contaminated soil, transport the soil to an appropriately permitted landfill, construct the PLC system, construct the ARAR-compliant caps, restore the site, and demobilize. The application rate of modified asphaltic concrete is similar to that of conventional asphalt pavement and significantly faster than constructing a multilayered cap. An additional 12- to 18-month period would be needed to conduct pre-design studies, prepare the remedial design (including all associated plans), and consult with appropriate agencies. Because exposure to contaminated soil would potentially continue until the on-property and off-property excavated material has been disposed off-site, protection would not be achieved for 2 years.

Alternative 4 would be equally effective in the short term as Alternative 2.

5.2.4.6 Implementability

The Alternative 4 soil containment component is easily implementable because construction of both a conventional multilayered ARAR-compliant cap and modified asphaltic concrete cap involves techniques, equipment, and procedures that are well proven and reliable. For the excavation and regrading of Area 1 and excavation of Area 3, contractor, equipment, and transport companies skilled in hazardous soil removal are readily available as is disposal capacity for the contaminated soil/fill. The construction of a modified asphaltic concrete cap would involve a local asphalt batch plant and local paving contractor.

Installation of the PLC uses established construction techniques. However, as discussed in Sections 5.2.2.6 and 5.2.3.6, construction logistics may be complicated by site topography, proximity to highways and railroads, and sequencing with reconfiguration of the Mouth of the West Ravine. Permits from local agencies should be readily available for temporary air permits for excavation and new or modified discharge permits for the waste stream from the groundwater treatment system.

5.2.4.7 Cost

The net present value of capital and operation and maintenance (O & M) costs associated with Alternative 4 is estimated to be \$22.0 million. These costs include capital costs for construction of the PLC system, excavation and disposal of contaminated material and containment of remaining on-site contaminated soil/fill. The cost for environmental monitoring and obtaining permits from local agencies is also included. The total capital cost estimate is \$19,309,000. Annual O&M costs are estimated to be \$219,000 per year. Table 5-3 presents a detailed breakdown of these costs.

6.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section presents a comparative analysis of remedial alternatives analyzed individually in Section 5. The comparative analysis of remedial alternatives evaluates the relative performance of each alternative with respect to seven of the NCP evaluation criteria described in Section 5.1. The first two evaluation criteria (overall protection of human health and the environment and compliance with ARARs) serve as threshold criteria in that they must be met by an alternative in order for the alternative to be eligible for selection. The next five evaluation criteria (long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost) serve as balancing criteria that are assessed so that major tradeoffs among the alternatives are identified and weighed in the decision-making process. The next criterion, known as a modifying criterion, is community acceptance. Community acceptance will be addressed in the DD following release of the SFS report and Preferred Plan, and after comment by the public on the Preferred Plan. The ninth criterion in the NCP is state acceptance, which is presumed when the DD is finally issued under the signature of the Director of Ohio EPA.

6.1 EVALUATION CRITERIA

The purpose of this comparative analysis is to identify the relative advantages and disadvantages of each alternative and thereby provide a sound basis for remedy selection that is consistent with the NCP. The NCP states, "The national goal of the remedy selection process is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste."

The comparative analysis presented in the following sections provides the information needed to decide which alternative best satisfies the goals and expectations consistent with the NCP. A summary of the components of each alternative follows.

Table 6.1 SUMMARY OF REMEDY COMPONENTS ACCORDING TO ALTERNATIVE

Area or Medium	Component	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Groundwater	Perimeter Leachate Control				
Area 1	Excavation, disposal Reconfiguration		, 2 ft (638 cy)	, 2 ft (638 cy)	, 2 ft (638 cy)
Area 2	Multilayered, vegetative Cap (ARAR – compliant)				
Area 3	Excavation and offsite disposal			, 1 ft (3,269 cy)	, 10 ft. (32,689 cy)
	Multilayered, vegetative cap, Above existing grade (ARAR-compliant)				
	Alternative cap, flush with existing grade (ARAR-compliant)				
Area 4	Asphalt pavement (ARAR-compliant)				
Area 5	Asphalt pavement (ARAR-compliant)				
	Continue Existing Interim Actions				
	Institutional Controls				

Notes: indicates that the alternative includes that component.

Ft = foot; cy = cubic yard; ARAR = applicable or relevant and appropriate requirement

6.1.1 Overall Protection of Human Health and the Environment

This section evaluates the overall protection of human health and the environment provided by each alternative.

Alternative 1 does not achieve protection of human health and the environment because no remedial action is taken. However, Alternatives 2, 3, and 4 will protect human health and the environment under current and likely future land uses through a variety of engineering, treatment, and institutional controls. Most of the remedy components are common to all three “action” alternatives. The PLC system represents a combined engineering and treatment control approach to mitigate risks to current or future receptors via the direct contact exposure route. The remedy for Area 1: Off-Property Mouth of the West Ravine utilizes an engineering approach (excavation and off-property disposal) to eliminate the risk posed via direct contact to receptors. The remedies for Areas 2, 4, and 5 also utilize engineering controls (ARAR-compliant containment) to control the risks posed to current and future receptors via the direct contact exposure route.

Additional protection to risks posed by direct contact and infiltration is provided through ARAR-compliant containment of Area 3. Containment of Area 3 is a common component to all three action alternatives with an ARAR-compliant cap constructed over the same surface area, or footprint, containing contaminated material determined to present the principal threat on site. The type of cap and level of excavation of Area 3 is the only variable component of the action alternatives.

Some short-term disruption to the environment and the community would be caused by construction activities involved in implementing all alternatives other than Alternative 1. This is primarily due to the off-property excavation and construction activities needed to reconfigure Area 1: Off-Property Mouth of the West Ravine and to install the PLC system. It is possible that some disruption of traffic on the Norwood Lateral south of the site will be required. At a minimum, special precautions must be taken to prevent creation of inadvertent traffic hazards as a result of construction activities. In addition, traffic disruption would likely result from the Area 3 excavation activities required in Alternatives 3 and 4. Alternative 4 would pose the greatest short-term disruption to the environment and the community because of more extensive excavation and offsite disposal activities. Alternative 2 would create the least risk to workers and the least disruption to the environment and the community because no additional excavation and off-property disposal activities would be involved.

6.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 1, the no action alternative, does not achieve the ARARs identified for the site in Table 2-3. Chemical-, location- and action-specific ARARs identified in Table 2-3 are pertinent to Alternatives 2, 3, and 4. All three of these alternatives would comply with the ARARs. In addition to compliance with ARARs, the control technologies in Alternatives 2, 3, and 4 would fulfill the NCP preference for treatment that minimizes cross-media transfer of contaminants.

All three action alternatives considered in this SFS include compliance, in Areas 2, 3, 4, and 5, with the solid waste rules for sanitary landfills specified in OAC 3745-27. Because of the circumstances and nature of the waste at the site, and critical routes of exposure in the various areas, a variance to the cap design would be required under all three action alternatives to allow an alternative cap such as modified asphaltic concrete for Area 3 and conventional asphalt pavement for Areas 4 and 5. Internal discussions within Ohio EPA indicate that an administrative variance to the solid waste landfill cap design would be feasible.

6.1.3 Long-Term Effectiveness and Permanence

This section evaluates the long-term effectiveness and permanence provided by each alternative.

All three action alternatives primarily involve a containment approach, along with other common components (PLC, Areas 1 and 2 remedy), to control exposure pathways and associated risk from onsite contaminated media. Material that exceeds the threshold risk criterion (ELCR greater than 10-6 or HI greater than 1) will remain on-property under all three action alternatives. Under Alternatives 2, 3, and 4, the contaminated soil/fill will be isolated from current and future human receptors by an ARAR-compliant cap. Should Alternatives 2, 3, or 4 be selected, the potential for residual risks from contaminants in the soil would remain, precluding unrestricted use of the site. Therefore, institutional controls are necessary to control land use. The effectiveness of Alternatives 2, 3, and 4 will depend on the enforcement of these land use controls and O&M and long-term monitoring programs to ensure the integrity of the remedy in the future.

The principal difference between the three action alternatives with respect to long-term effectiveness and permanence is in the increased excavation and disposal volume from Alternative 2 (~1,400 cy) to Alternative 3 (~4,600 cy) to Alternative 4 (~34,000 cy). The benefit of long-term risk reduction through excavation and off-property disposal used in Alternative 3 and Alternative 4 provide an advantage over Alternative 2, where the cap is constructed upon the existing grade with no excavation (none in addition to that associated with Area 1 and the PLC trench). Should the long-term enforcement of land use controls or engineered containment fail, Alternative 4 would provide more permanence in the long term by removing the greatest volume of contaminated material determined to present the principal threat.

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This section evaluates the reduction of toxicity, mobility, or volume through the treatment of contaminants under each alternative.

Alternatives 2, 3 and 4 would all use treatment to reduce the toxicity and volume of contaminated water after it is collected in the PLC system. Alternatives 2, 3, and 4 may use off-site treatment of excavated on-site material that is determined to be a hazardous waste in order to meet land disposal restrictions (LDRs) described in OAC 3745-59. None of the alternatives would use treatment to reduce the toxicity, mobility or volume of contaminated on-site soil/fill at the site. Therefore, the three action alternatives are equal in terms of rank of reducing toxicity, mobility, or volume through treatment.

6.1.5 Short-Term Effectiveness

This section evaluates the short-term effectiveness of each alternative.

Alternative 1 would provide the highest level of short-term protection to the community, workers, and the environment because no site construction would be required under this alternative. Alternatives 2, 3, and 4 all involve excavating contaminated soil/fill, however, Alternative 4 is considered to have less effectiveness in the short term because of the extensive on-site excavation of the contaminated soil/fill. Alternative 4 could cause an additional short-term risk to the community because of the increased number of truck trips that would occur while transporting soil/fill off site for disposal. However, there are proven and easily implemented practices for mitigating the short-term effects from excavation and transport of contaminated material which can be applied to all alternatives with equivalent success.
Alternative 1 would have no impact on the environment because no construction activities would be involved. Alternatives 2, 3, and 4 would have short-term adverse impacts to the environment in proportion to the amount of soil excavated. Specifically, fugitive emissions from construction activities might temporarily impair air quality or surface water runoff of contaminated material might adversely impact Duck Creek. As discussed above however, there are several proven and implementable construction techniques to eliminate these impacts.

The estimated amount of time to implement Alternatives 2 and 4 is about 6 months. The estimated amount of time to implement Alternative 3 is slightly less, 4 months, because of the shorter time to construct a modified asphaltic concrete cap compared to a multilayered, vegetative cap in Alternative 2 and because of the limited excavation in comparison to Alternative 4.

6.1.6 Implementability

This section evaluates the implementability of each alternative.

Alternative 1 would be readily implementable because no action would be taken. Alternatives 2, 3, and 4 are equally implementable because they rely on established technologies and construction practices. The construction of a multilayered, vegetative cap (Alternative 2) is well established in the construction industry. The construction of a modified asphaltic concrete cap (Alternatives 3 and 4) is readily implementable because of the availability of batch plants and paving equipment. Logistically, the Area 3 component of Alternative 2 would be easier to implement than the Area 3 components of Alternatives 3 and 4. This is because the excavation, staging and transport of contaminated soil/fill would require a higher level of coordination over a longer period of time than the installation of a multilayered, vegetative cap directly over the contaminated material. Alternative 4 would be the most logistically complex because it involves the greatest excavation volume.

All three-action alternatives involve on-site treatment and off-site disposal of contaminated groundwater, so the need for a new discharge permit or the modification of the existing discharge permit will affect all three action alternatives equally. The problematic logistics of conducting construction operations in the Ohio DOT right-of-way along the Norwood Lateral will also impact all three action alternatives equally.

6.1.7 Cost

This section compares the present worth value of each alternative. These cost figures are expected to have an accuracy of between minus 30 and plus 50 percent.

No known costs would be associated with Alternative 1. The total capital and O&M costs associated with each action alternative are summarized below.

Table 6-2 SUMMARY OF PRESENT WORTH COSTS

30-Year Present Worth Cost Estimate	Alternative 2 ($)	Alternative 3 ($)	Alternative 4 ($)
Capital	4,074,000	4,594,000	19,309,000
Operations & Maintenance	2,854,000	2,718,000	2,718,000
Total Present Worth	6,928,000	7,312,000	22,027,000

The difference in capital costs is primarily attributable and directly proportional to the volume of excavated and disposed soil associated with Area 3, with costs increasing from $1,152,656 (Alternative 2, Area 3 excavation and disposal = 0), to $1,512,751 (Alternative 3, Area 3 excavation and disposal = 3,269 cy), to $11,705,459 (Alternative 4, Area 3 excavation and disposal = 32,689 cy). The higher O&M cost associated with Alternative 2 is attributed to the vegetative cap for Area 3, which is more costly to maintain than modified asphaltic concrete.

6.2 COMPARATIVE ANALYSIS OF ALTERNATIVES SUMMARY

The comparative analysis indicates that Alternative 1, no action, will not be protective of public health and the environment. Alternatives 2, 3, and 4 meet the threshold criteria of overall protection of human health and the environment, as well as compliance with ARARs. Because of the greater volume of soil removed from the site, Alternatives 3 and 4 are somewhat less effective in the short term and somewhat more logistically complex to implement. However, Alternatives 3 and 4 have greater long-term effectiveness and permanence compared to Alternative 2 because of the greater volume of soil removed from the site.

Cost-effectiveness is evaluated by considering the long-term effectiveness and permanence; reductions in toxicity, mobility, or volume through treatment; and short-term effectiveness to assess overall effectiveness. Overall effectiveness is compared to cost and a remedy is considered cost-effective if its costs are proportional to its overall effectiveness. Alternatives 2 and 3 are judged to be more cost effective than Alternative 4 because the costs are more proportional to the overall effectiveness of the remedies.

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APPENDIX A

PAYNE FIRM RI – SITE RISK TABLES

APPENDIX B

PAYNE FIRM FS – PRG TABLES

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PAYNE FIRM FS – ARARs TABLE

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RACER COST ANALYSIS BACKUP

DRAFT

STREAMLINED FEASIBILITY STUDY
FOR THE EM SCIENCE SITE
CINCINNATI, OHIO

November 2001

Prepared by
Ohio Environmental Protection Agency
Division of Emergency & Remedial Response
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Appendix

1.0 INTRODUCTION

As part of a Remedial Investigation/Feasibility Study (RI/FS), the Ohio Environmental Protection Agency (Ohio EPA) has prepared this streamlined Feasibility Study (FS) report for the EM Science site (Site) in Cincinnati, Ohio. EM Science is a division of EM Industries, Inc. Hawthorne, New York. The Site is a chemical manufacturing facility that provides chemicals to laboratories and other commercial and industrial manufacturers. This FS identifies and evaluates a range of remedial alternatives to address contamination at the Site, which was evaluated during the Remedial Investigation (RI).

On December 24, 1992, EM Science entered into an Administrative Order on Consent (AOC) with the Ohio EPA to complete a RI/FS at the Site. Section 1.3.3 describes activities at the Site prior to the AOC. The RI/FS required activities were presented in EM Science's *Work Plan for Remedial Investigation/Feasibility Study, EM Science site, Cincinnati, Ohio* (RI/FS Work Plan) dated November 19, 1993. The purpose of the RI/FS is to characterize the nature and extent of risks posed by soil and perched ground water contamination beneath the Site, and to evaluate potential remedial alternatives for mitigating the risks.

EM Science conducted RI activities at the Site between February 1994 and October 1996. The results of the RI are presented in the approved *Remedial Investigation Report for the EM Science Site, Cincinnati, Ohio* (RI Report), dated October 26, 1996. FS activities were conducted between November 1996 and January 2000. EM Science submitted a Draft FS Report to Ohio EPA on May 27, 1999. Ohio EPA noted deficiencies and violations of the Director's Findings and Orders (F&Os) presented in the AOC. EM Science submitted a Revised Draft FS Report to Ohio EPA, dated January 21, 2000. Ohio EPA again noted deficiencies and violations with the F&Os. Pursuant to Section XIV of the F&Os, Ohio EPA opted to complete the EM Science draft FS Report. The history of this decision is summarized in Ohio EPA's letter to EM Science dated December 8, 2000. This FS includes sections of EM Science's draft FS Report that were accepted by Ohio EPA. Text from the EM Science draft FS is highlighted in this FS report. Sections that were added or revised by Ohio EPA in order to comply with appropriate guidance and regulations are shown in non-highlighted text.

This FS report was prepared in a manner consistent with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988) and with 40 CFR Part 300, the National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule (NCP). The following sections describe the purpose and scope of the FS report and the organization of the report, and provide a summary of the site background and history.

1.1 PURPOSE AND SCOPE

This report evaluates possible methods for removing, treating, or containing contaminated soil/fill and perched ground water beneath the Site such that potential risks to human health and the environment are eliminated or minimized. The requirements of the FS are outlined in Section 6.0 of the RI/FS Work Plan, and TASK 8 (Development and Screening of Remedial Alternatives), TASK 9 (Treatability Study), and TASK 10 (Detailed Analysis of Remedial Alternatives) of the Ohio EPA's Generic Statement of Work Remedial Investigation/Feasibility Study (SOW), which was attached to the AOC. This report was preceded by EM Science's October 3, 1997 Remedial Action Objectives Technical Memorandum No. 10, EM Science RI/FS, Cincinnati, Ohio (RAO TM), and July 6, 1998, Alternative Arrays Report Technical Memorandum No. 14, EM Science RI/FS, Cincinnati, Ohio (AA Report). As required by the SOW, these were submitted to the Ohio EPA as interim documents and portions of the FS Report.

Consistent with the RI/FS Work Plan, SOW, NCP, and RI/FS Guidance, this report examines an appropriate range of RAs. The FS primarily relies upon data presented in the RI Report for developing and analyzing an appropriate range of remedial action alternatives. The NCP requires that nine criteria be considered during development of the remedial alternatives. These criteria include long- and short-term effectiveness, implementability, overall protection of human health and the environment, cost, adherence to applicable or relevant and appropriate requirements (ARAR), contaminant reduction, and state and public acceptance. The first seven criteria (Seven Evaluation Criteria) are used to evaluate each RA individually and in comparison to all other RAs. The Ohio EPA will use this information during selection of a preferred alternative. Because this FS is developed by Ohio EPA, "state acceptance" criteria will not be specifically considered in this FS.

The overall intent of this FS Report is to use available RI data, existing remedial engineering literature, treatability study results, and U.S. EPA guidance documents and technical reports to make supportable decisions during the development and detailed and comparative analysis of the RAs. Consistent with the RI/FS Guidance, FS cost estimates fall within a range of +50 percent to –30 percent. To provide a uniform basis for cost comparisons, RA cost estimates are presented in present worth costs. Present worth costs reflect the quantity of money, which must be placed in a bank today at a set interest rate, termed the discount rate, to pay for the remedial action over the life of the project.

During the FS, additional data was acquired from specific areas of the site to further define certain site characteristics documented in the RI Report, and to provide sufficient data to allow in-situ treatment technologies and options to be fully evaluated to support the development of RAs. These additional data needs involved the drilling of additional soil borings, installation of additional monitoring wells, the completion of a pumping test in the Upper Sand Unit, and the performance of three on-Site treatability studies. Relevant Technical Memorandums (TM) and Technical Amendments (TA) that were prepared and submitted to the Ohio EPA for review and approval during the FS are listed on
. The purpose of these interim documents was to summarize the tasks and results associated with the work that was performed, and to reduce costs and performance uncertainties for treatment process options so that appropriate RAs could be developed.

The remedial technologies tested by The Payne Firm (a consultant for EM Science)and selected sub-contractors were soil vapor extraction (SVE), dual phase extraction (DPE), and hydraulic fracturing. Each is an in-situ technique, intended respectively to recover VOC vapors, recover VOC vapors and ground water, or to improve the permeability of Site soils. The proposed scope of the combined SVE and DPE treatability study was presented to the Ohio EPA in The Payne Firm's Final Work Plan, Treatability Study, Phase II, submitted April 22, 1998 and modified on May 12, 1998, which was approved in a letter from the Ohio EPA dated May 15, 1998. The results of the SVE and DPE treatability studies were submitted to the Ohio EPA in Technical Memorandum No. 15, Final Results, Treatability Study-Phase II on September 29, 1998 and approved in a letter from the Ohio EPA dated November 4, 1998. The tasks for the hydraulic fracturing treatability study were presented in the Work Plan, Treatability Study Phase III, Fracture-Enhanced Soil Vapor Extraction, submitted to the Ohio EPA on October 1, 1998, approved by the Ohio EPA in a letter dated October 23, 1998. Data collected during the hydraulic fracturing feasibility study and conclusions drawn were presented in The Payne Firm's Technical Memorandum No. 16, Results, Fracture-Enhanced Soil Vapor Extraction, Treatability Study Phase III, which was submitted to the Ohio EPA on January 14, 1999 and approved by the Ohio EPA in a letter dated February 8, 1999. In addition, TM-12 summarized the feasibility of ground water pumping from the Upper Sand Unit to reduce contaminant mass; and, TM-13 summarized the results of additional soil borings that were drilled at the Mouth of the West Ravine to further define the geology and distribution of VOCs in the vicinity of a proposed surface water collection sump.

1.2 REPORT ORGANIZATION

This report is organized into seven Sections:

Section 1.0 Introduction - The remainder of this section presents a Site description, summary of the history of the EM Science Site, and a general summary of the RI Report. Additional details regarding these issues can be located in the RI/FS Work Plan and the RI Report, which are available in the Ohio EPA's files.

Section 2.0 Remedial Action Objectives – This section identifies remedial action objectives (RAOs) and preliminary remediation goals (PRGs) for contaminated media at the Site. In addition, this section describes applicable or relevant and appropriate requirements (ARARs) as required by the NCP that are pertinent to the alternatives discussed in this FS.

Section 3.0 Screening and Identification of Technologies and Process Options - The results of identifying and screening remedial technologies and process options for soil/fill and perched ground water are presented in this section.

Section 4.0 Development of Remedial Action Alternatives - This section explains the development and assembly of alternatives using the screening information presented in Section 3.0, and presents a detailed description of the alternatives being considered.

Section 5.0 Detailed Analysis of Remedial Action Alternatives - The results of a detailed evaluation of the alternatives assembled in Section 4.0, using seven of the eight pertinent NCP evaluation criteria, is presented in this section.

Section 6.0 Comparison of Remedial Action Alternatives – This section compares the ability of each of the alternatives to satisfy the seven NCP evaluation criteria.

1.3 SITE BACKGROUND

This section is a general overview of the chemical, physical, operational, and regulatory aspects of the EM Science Site.

1.3.1 Site Description

EM Science is a Division of EM Industries, Inc., Hawthorne, New York. The EM Science property is comprised of nine acres in the Northern 1/2, Northwest 1/4, Section 28, Fractional Range 2, Township 4, Miami Purchase, Cities of Norwood and Cincinnati, Hamilton County, Ohio with latitude 39° 9' 55" and longitude 84° 26' 10" (see Figure 1-1). The EM Science facility is located northwest of the intersection of Interstate 71 (I-71) and State Route 562 (also referred to as S.R. 562 or "Norwood Lateral"). The Site is bounded by Highland Avenue on the north, the Norwood Lateral on the south, Shepherd Chemical Company on the west, and a Norfolk Southern railroad embankment on the east (see Figure 1-2). The western portion of the property lies within the City of Norwood and occupies approximately 6.62 acres. The eastern portion of the EM Science property is located within the City of Cincinnati and occupies approximately 2.38 acres. Most of the plant operations through the years have been conducted on the Norwood portion of the property. The EM Science property is almost entirely paved with concrete or asphalt except for some gravel covered areas in the central and southern portions of the facility, and a grassy area east of Building 14.

The EM Science property is located in a mixed commercial/industrial/residential setting. The areas west and north of the facility consist predominantly of industrial manufacturing, warehousing, chemical production, and service companies. A few residential houses are located northwest of the EM Science property along Highland Avenue. Immediately beyond the Norfolk Southern railroad embankment, the topography east of the facility steeply slopes to a lower parking lot belonging to Duramed Pharmaceutical, Inc. South of the EM Science property, the Norwood Lateral and associated on and off-ramps separate the facility from I-71 and a residential area located 500 feet southwest of the property. The original topography of the property included two ravines associated with the Duck Creek drainage system (referred to as the former East Ravine and former West Ravine in the RI/FS Work Plan). The geology and hydrogeology, and contamination associated with these ravines are discussed in Sections 1.3.2 and 1.3.3.2, respectively. Duck Creek is situated in a concrete channel located approximately 600 feet southeast of the EM Science facility. The East and West Ravines have been filled to present grade which slopes from an elevation of 614 feet above mean sea level (MSL) on the western perimeter of the property to approximately 598 feet MSL along the eastern property boundary. South of the EM Science property, the surface slopes abruptly (a 2:1 engineered slope developed during the Construction of the Norwood Lateral in the late 1960s) from an elevation of approximately 606 feet MSL to 580 feet MSL along the Norwood Lateral.

1.3.2 Geology and Hydrogeology

The Site Geological Model (SGM) consists of three main hydrostratigraphic systems: a Perched Ground Water System, a Confining System, and a Confined Aquifer System (see Figure 1-3). The Confined Aquifer System (i.e., Norwood Trough Aquifer) is separated from the Perched Ground Water System by approximately 100 feet of non-saturated deposits associated with the Confining System. The extensive amount of geological and geotechnical data used to develop the SGM demonstrated that there are limited pathways for horizontal or vertical contaminant migration beneath the Site. Potential contaminant migration horizontally is restricted to discontinuous perched ground water zones within the Perched Ground Water System. Vertically, migration is restricted by silt and clay deposits associated with the lower portion of the Perched Ground Water System (i.e., Lacustrine and Lower Clay Units), and the units within the Confining System which include: the 10 to 30 feet thick Lower Till Unit which is present beneath the entire Site; and, underlying the Lower Till Unit, the 90 to 100 feet thick unsaturated, partially cemented, silt, sand, and gravel deposits situated below the upper portion of the Norwood Trough Sand and Gravel Unit (i.e., Upper Non-Saturated Zone).

The hydrogeology varies considerably within the predominantly silt and clay-rich Perched Ground Water System. Ground water is restricted to discontinuous sand seams and lenses, and to the backfill of storm sewers. Perched ground water is more prevalent beneath the central and eastern portions of the Site where coarser seams and lenses exist. The majority of the monitoring wells screened within the Perched Ground Water System are low yielding and slow to recharge.

The low permeability clays and silts, which dominate the Perched Ground Water System, behave as an aquitard that can store perched ground water but transmit it slowly from one porous saturated zone to another. Flow directions in the Perched Ground Water System are artificially controlled by the French Drain and P6A (when pumping). No perched ground water exists in the Confining System. The Norwood Trough Aquifer, situated at a depth of 175 feet below the facility, was demonstrated to be under confined conditions beneath the Site.

A summary of the relevant issues associated with the Site physical setting is presented below:

- The EM Science Site is situated within the Norwood Trough buried glacial valley. The bottom of the Norwood Trough lies at about 375 feet MSL, or approximately 235 feet below the Site. The bottom two-thirds of the Norwood Trough are filled with fining upward outwash sand and gravel deposits that are up to 125 feet thick; the upper one-third consists of 80 to 125 feet of glacial tills, glaciofluvial, and glaciolacustrine deposits. The Norwood Trough Aquifer (NTA), a U.S. EPA designated sole source regional aquifer, exists in the basal saturated portion of the outwash sand and gravel deposits. Within a one-mile radius of the Site, ground water pumped from the NTA is used solely for industrial production purposes; no water derived from the NTA is utilized for drinking.

- The Site is located within the Little Miami River drainage basin above the 100-year flood plain. The nearest surface water body is Duck Creek located 600 feet southeast of the EM Science property. In the vicinity of the Site, Duck Creek is an ungaged stream with no measured peak flows and is predominantly confined to aboveground and belowground-engineered concrete channels. The 84-inch storm sewer at the bottom of the former East Ravine discharged into Duck Creek southeast of the facility. Besides Duck Creek, no other significant surface water bodies are located in the vicinity of the Site.

- The three hydrostratigraphic systems within the SGM are summarized below:

1. Perched Ground Water System

The Perched Ground Water System occurs within the upper portion of the SGM and consists of the following three sub-systems:

Vadose Zone - The Vadose Zone consists of the upper 30 to 40 feet of fill and glacial overburden including deposits of the Upper Till Unit and the fill of the former West and East Ravines. The Vadose Zone is predominantly unsaturated except for perched ground water occurring in: thin sand seams in the Upper Till Unit; the fill of the former West and East Ravines; and, the backfill of the 84-inch and 27-inch storm sewers. Monitoring wells screened in the Vadose Zone are low yielding and slow to recharge.

Fill material within the Vadose Zone has been placed across the entire property and can be divided into three main categories: 1) general surficial soil/engineering fill situated above the Upper Till Unit; 2) the fill of the former West Ravine; and, 3) the fill of the former East Ravine. The characteristics of these three fill types are extensively described in Section 3.4.1.1 of the RI Report. The latter two categories are more important to the FS process, and are described in general below:

Former West Ravine Fill - The former West Ravine is located in the central portion of the facility. The former West Ravine fill material primarily consists of a clay and silt matrix with varying amounts of sand, gravel, broken pieces of glass, larger fragments of concrete, wood and metal construction debris, wood chips, and frequent soil staining. Lesser amounts of debris are present in the upper northwestern portion of the ravine (Upper West Ravine) than in the southeastern portion (Middle West Ravine). Large slabs of concrete, logs, glass bottles, rubber car tires, metal strips, and plastic bottle caps are visible near the bottom of the fill material at the mouth of the former West Ravine (Mouth of the West Ravine). At the Mouth of the West Ravine, the fill material slopes down the steep walls of the former ravine and represents the terminus of filling activity. The Outfall which discharges water from the ravine is present at the south end of the fill. Three on-property test pits dug into the first upper 10 feet of the fill material during previous Site investigations in the late 1980s also encountered the same type of fill materials described above.

According to the RI Report, the thickness of the fill increases from the northwest to the southeast with the thickest portions occurring along the longitudinal axis of the former ravine. The fill material becomes increasingly thinner perpendicular to the ravine axis reflecting the placement of materials on the slope of the former West Ravine. Fill material is not present south of the Outfall except surficially along the walls of the former ravine. The fill of the West Ravine sits on top of the Upper Till Unit everywhere except at the southeastern one-third portion of the former ravine. As discussed in the RI Report, the channel of the former ravine progressively eroded soils from northwest to southeast. In the lower portion of the Middle West Ravine and at the Mouth of the West Ravine, the Upper Till Unit is completely eroded away and the fill material sits directly on top of the Lacustrine Unit.

Ground water flowing along the base of the West Ravine fill discharges to concrete ditches at the Outfall and at Seep-562; the conduits funnel discharged water to Sump-562. The fill in the former West Ravine is non-engineered and heterogeneous and is, therefore, conducive to the occurrence of voids and channels. Some of the discharge from the Outfall and Seep-562 may originate from perched ground water voids in the fill that are recharged by water flowing into the fill from Upper Till sand seams. Because the majority of the facility is capped with asphalt and concrete, and EM Science maintains an active storm water management program, a very limited infiltration may contribute to a small part of the discharge at the Mouth of the West Ravine. During the RI field investigation, the baseflow discharge at the Outfall was approximately 0.5 gallons per minute (gpm). During rain events, the discharge increased to approximately 5 to 10 gpm, but then decreased back to baseflow soon after the rain event ceased. The discharge at Seep-562 was too negligible to quantify during the field investigation.

East Ravine Fill - Prior to completion of the RI, the environmental implications associated with the fill of the former East Ravine were not determined during previous Site investigations because historical review indicated that the material was primarily soil and construction material derived from off-property sources. More emphasis was placed on investigating the fill of the former West Ravine since most of the materials were derived from on-property sources. In the RI/FS Work Plan, it was determined that there was a need to confirm that East Ravine fill was not derived from, or impacted by, historical on-property operations.

The fill of the former East Ravine resembles the surficial fill encountered outside the boundaries of the former West Ravine. It consists predominantly of soft to medium dense silt and clay with minor amounts of sand, gravel, and small pieces of brick, concrete, asphalt, and wood debris. Some larger pieces of typical construction debris (e.g. plywood, drywall, plastic sheeting) were sparsely encountered in the first 15 to 20 feet of the fill at a few of the boring locations drilled during the RI. In contrast to the West Ravine fill, no widespread occurrence of broken glass, plastic caps, or soil staining was observed. Also in contrast, the thickness of the fill remains consistently between 32 and 36 feet along the northwest to southeast trending axis of the former East Ravine. This occurs because the former East Ravine was a more elongated and broadly shaped drainage ravine extending approximately 200 to 250 feet north and south of the property line before it was filled. As discussed in the RI Report, the western wall of the former East Ravine was more steep than the gently sloping eastern wall which contributed to: 1) the broadness of the ravine and the relative consistency in the thickness of fill encountered in soil borings; and, 2) the extension of fill material beyond the northern, eastern, and southeastern property boundaries.

Similar to the West Ravine, the geologic development of the East Ravine eroded away most of the Upper Till Unit and the majority of the Lacustrine Unit. North of a line that extends from borings VE402 east to VZ408 and VZ409, (see Figure 1-4), the East

Ravine fill sits on top of silt and fine grained sand deposits associated with the top of the Lower Clay Unit. South of that line, the Lower Clay Unit is more silt and clay rich.

Beneath the fill of the former East Ravine, backfill materials around the 84-inch storm sewer pipe, which traverses the longitudinal axis of the ravine, contain perched ground water. Monitoring wells MW18, MW23, and MW506 are monitoring the perched ground water, which is derived from infiltration. Perched backfill ground water monitored at the eastern property at MW18 and MW23 is believed to flow into the seep and Sewer C, and downgradient to MW506 located approximately 225 feet southeast of the property. The ground water elevation at MW506 is approximately 4 feet lower than the elevation observed at MW23 as depicted on the Vadose Zone potentiometric maps in Appendix J of the RI Report. In addition, monitoring well MW504 monitors perched backfill ground water that flows from the vicinity of Sump-562 to the area beneath the S.R. 562 median.

2. <u>Confining System</u>

Beneath the Perched Ground Water System is a Confining System, which is situated above the Norwood Trough Aquifer (Figures 1-3). The Confining System is approximately 100 to 110 feet thick and consists of the Lower Till Unit (including the Lacustrine 3 Zone), and the unsaturated deposits of the Norwood Trough Sand and Gravel Unit (i.e., Upper Non-Saturated Zone). No saturated sand seams or pockets were observed in the numerous borings drilled into the Lower Till Unit, or in four borings drilled into the Upper Non-Saturated Zone. The Lower Till Unit is situated between 65 and 80 feet below the Site and is present beneath the entire Site. The dense, homogenous unit ranges between 12 and 31 feet thick. The hydraulic conductivity values in the Lower Till Unit typically ranged between 1×10^{-8} and 1×10^{-9} cm/s, which were the lowest values observed in the SGM. The mean moisture content for the 32 samples collected from the Confining System was approximately 11.2% indicating non-saturated conditions.

3. Confined Aquifer System

The 50 feet thick Lower Saturated Zone of the Norwood Trough Sand Gravel Unit (i.e., Norwood Trough Aquifer or Confined Aquifer System) exists beneath the Confining System. Beneath the Site, the Norwood Trough Aquifer (NTA) is under confining conditions as demonstrated by the ground water elevation test at LT338. Thick sequences of shale and limestone bedrock exist beneath the NTA. The 100 feet thick unsaturated Confining System between the bottom of the Perched Ground Water System and the top of the NTA indicate that it is very improbable that contaminants detected below the Site will migrate to the NTA.

- Potential vertical contaminant migration within the SGM is limited by the silt and clay rich nature of the Upper Till, Lacustrine, Lower Clay, and Lower Till Units. The geotechnical properties of these units have assisted in impeding the widespread vertical migration of contaminants from on-property areas of contamination. The thickness characteristics and homogeneous nature of the Lower Till Unit, in combination with the unsaturated properties of the Non-Saturated Zone of the Norwood Trough Sand and Gravel Unit, reduce the potential for contaminants to migrate beneath the Perched Ground Water System.

- Ground water flow in the Perched Ground Water System is primarily west to east beneath the property (Figures 1-3). Potential horizontal contaminant migration routes within the Perched Ground Water System are restricted to: 1) man-made conduits within the Vadose Zone; 2) the Upper Sand Unit in Perched Zone I where migrating contaminants are captured by the French Drain; and, 3) Perched Zone II deposits situated beneath the central and southern portions of the Site. The horizontal migration of contaminants beneath the central portion of the Site in Perched Zone II is restricted by pumping well P6A. Beneath the southern portion of the Site, migration is restricted by the limited hydraulic capabilities of thin, discrete, silty sand seams within the clay-rich Lacustrine Unit. In the Vadose Zone, Sump-562 captures perched ground water flowing from the Outfall and from the Seep-562. The only other routes of migration in the Vadose Zone include the backfill around the 27-inch and 84-inch storm sewers, and the seep at Sewer C in the 84-inch storm sewer. These routes are severely limited, however, by the low availability of perched ground water and the lateral extent of the sewer lines.

- A limited hydraulic gradient test at conducted P6A during the RI indicated that: 1) the potential horizontal contaminant migration route from the central portion of the facility to the eastern property boundary in Perched Zone II (in the absence of pumping at P6A) is restricted by the heterogeneity of the deposits within the Lacustrine and Lower Clay Units; and, 2) monitoring well MW23 (screened in the backfill of the 84-inch storm sewer along the eastern property boundary) is in very limited hydraulic communication with P6A. The heterogeneity of the Perched Zone II deposits restricts the ability to quantitatively determine the rate of contaminant movement from the area south of Building 10 to the eastern property boundary during non-pumping conditions at P6A.

- Population within a one-mile radius of the Site is approximately 23,000 residents. Slightly more than one-half of the one mile area is residential, and the other half being industrial or commercial property, transportation corridors, parks, or undeveloped land. No areas allowing recreational hunting or fishing are present within one mile of the Site.

1.3.3 Site History

This section describes the site ownership and development history, historical source areas, administrative history, and interim actions.

1.3.4 Site Ownership and Property Development

The EM Science property is composed of three previously existing parcels that were acquired by previous owners of the facility. The property is almost entirely paved and contains numerous production, warehousing, and office buildings along with other existing chemical manufacturing and storage structures (see Figure 1-2). During the RI and previous investigations, numerous on-property and off-property monitoring wells were constructed as shown on Figure 1-4. The construction, screen interval, and soil strata and ground water intersected by post-RI monitoring wells are also presented in Table 1-2. The filling of the former West Ravine with soil, waste materials, and other debris by previous owners of the facility occurred between 1952 and 1971. A 15-inch storm sewer was placed at the base of the West Ravine as it was progressively filled from the northwest to the southeast. The slope of the fill of the West Ravine and the terminus of the storm sewer (or Outfall) are situated within the mouth of the West Ravine, which is located at the southeastern corner of the facility. The East Ravine was filled with soil and construction debris between 1938 and the early 1970s. There is no record of chemical placement in the East Ravine. An 84-inch storm sewer constructed by EM Science exists within the former channel of the East Ravine.

1.3.5 Historical Source Areas

Areas that were potential historical chemical release locations at the EM Science facility include:

1. **Middle West Ravine** - The central and southeastern portion of the property, consisting primarily of the fill in the West Ravine and underlying soils, impacted by the release of virgin and off-specification chemicals and diluted spent oleum. Contaminated ground water discharged from the Outfall is collected by a concrete sump (Sump-562) in the West Ravine mouth. EM Science constructed Sump-562 in 1983 as an interim action.

2. **Building 10 Area** - The area immediately south of Building 10 (a former chemical distillation and production building). This area contained a process sewer line that ran from the Building 10 to the West Ravine where it discharged to the ground. Contaminants originating from the process sewer have migrated to perched ground water that is captured beneath the eastern portion of the facility by a French Drain collection system. The French Drain was constructed by EM Science in 1988 to prevent off-property contaminant migration. In 1992, EM Science constructed and began operations of an interim action gradient control well (P6A), located beneath the western edge of the former East Ravine. Its purpose is to prevent the migration of perched ground water contaminants in coarse-grained deposits beneath the French Drain to the eastern property boundary.

3. **Building 4 Area** - A trench drain discharged at the northeast and southeast corners of building 4. Approximately 40 feet farther east a chemical Tank Farm formerly existed. The former Tank Farm contained aboveground and belowground tanks that stored bulk chemicals used in previous manufacturing processes. Contaminants originating from this area of the property have migrated to a ground water seep (Seep-562) located along an engineered cut-slope west of Sump-562. This seepage is also collected by Sump-562.

4. **East Ravine and Upper West Ravine** – These areas were filled primarily with soil and small amounts of construction debris. Risk analysis performed during the RAO indicated both areas pose no unacceptable risks to human health and the environment beyond extended direct contact or inhalation of contaminated soil particles.

1.3.6 Administrative History

In 1981, the U.S. EPA and Ohio EPA analyzed leachate collected at the mouth of the West Ravine during Resource Conservation Recovery Act (RCRA) inspections of the facility. In response to this initial data collection activity, EM Science began to voluntarily assess the nature and extent of contamination at the Site. An initial "Draft RI/FS Work Plan" was submitted to the Ohio EPA in 1985 and EM Science proceeded with "voluntary RI" sampling activities focused on identifying potential contaminant source areas and off-property contaminant migration pathways. The work scopes and tasks were primarily focused on: 1) obtaining technical data to support responsible party litigation against previous owners of the facility; 2) identifying contaminant source areas where known releases occurred; 3) assessing the waste characterization and volume of contaminated materials in the West Ravine; and, 4) collecting hydrogeological and contaminant data for the implementation of interim remedial actions.

Subsequently, three "Draft RI Reports" dated November 7, 1986, November 10, 1988, and February 7, 1990, were submitted to the Ohio EPA by EM Science documenting the results of the voluntary investigations. The Ohio EPA provided comments to each of the Draft RI Reports to assist EM Science in identifying potential data gaps in its voluntary assessment. A bibliography of the applicable existing documents associated with the 1981 to 1990 investigations was presented in

Section 2.3.1.0 of the RI/FS Work Plan (p. 2-27 to 2-28).

In a May 31, 1992 letter, the Ohio EPA invited EM Science to enjoin in an AOC that would "govern the management and completion of future EM Science RI/FS activities". As a result, EM Science and the Ohio EPA entered into an AOC to conduct a comprehensive RI/FS for the Site following the Ohio EPA RI/FS SOW on December 24, 1992.

Pursuant to the AOC, EM Science submitted a RI/FS Work Plan and supporting documents to the Ohio EPA, which was approved on February 28, 1994. The RI/FS Work Plan reviewed pertinent historical data associated with the Site in Sections 2.3.0 (Previous Investigations, p. 2-26 to 2-38) and 3.1.0 (Review of Existing Data, p. 3-1 to 3-14). The review of the existing data indicated that four primary data gaps were present: 1) a complete definition of the nature and extent of soil and ground water contamination at the Site; 2) a thorough hydrogeological assessment of deeper lacustrine, till, and sand and gravel deposits beneath the Site; 3) a complete quantification of the actual or potential risks to human health and the environment; and, 4) a quantitative analysis of the representativeness and usability of the existing analytical data base. Subsequently, EM Science and The Payne Firm completed the RI tasks in the RI/FS Work Plan from February 1994 to October 1996 to address these and other related minor data gaps.

1.3.7 Feasibility Study

After the RI tasks were completed in 1996, EM Science and the Payne Firm began work on an FS. EM Science submitted a Draft FS Report and a Revised Draft FS report to Ohio EPA in May 1999 and January 2000, respectively. In December 2000, the Ohio EPA notified EM Science that the agency would complete the FS in order to correct deficiencies in the report. This document is the result of that effort and includes sections of EM Science's draft FS Report (highlighted text).

1.3.8 Interim Actions

During the voluntary investigations undertaken by EM Science prior to the 1992 AOC, four interim actions were implemented by EM Science during the 1980s and early 1990s. The interim actions consisted of a: 1) surface water collection sump; 2) storm water management program; 3) French Drain ground water collection system; and, 4) hydraulic gradient control ground water collection pump (see Figure 1-2). These actions were taken to mitigate the migration of contamination off-property identified during field activities, and thereby reduce the potential for exposure to human health and the environment.

Implementation of the interim actions required interaction with appropriate governmental or regulatory agencies before installation. Specifically, the surface water sump and small concrete trough at the Mouth of the West Ravine in the right-of-way of S.R. 562 was permitted by the Ohio Department of Transportation (ODOT). ODOT also permitted installation of a fence around the surface sump to protect human health and the environment. The MSD and Ohio EPA issued a PTI and PTO for the sump discharge to the MSD POTW. A PTI and PTO was also issued for discharges to MSD from the French Drain and P6A.

In accordance with the RI/FS Work Plan, an Interim Action Efficacy program was conducted during the RI to technically evaluate each of the existing interim actions. The program demonstrated that each interim action was performing at a level consistent with its original performance objectives and goals. The results were documented in The Payne Firm's Interim Action Efficacy Report (Efficacy Report), which was approved by the Ohio EPA on March 20, 1995.

Specific monitoring tasks are completed each month by EM Science to further evaluate the efficacy and reliability of two of the interim actions (Outfall surface water sump and French Drain). The results of the tasks are presented in the Monthly RI/FS Report required by TASK 11 of the SOW. Besides the four pre-RI interim actions, two additional interim actions were completed by EM Science. A fencing interim action was emplaced during the RI, and a hot spot soil delineation and removal interim action was conducted during the FS. The following paragraphs provide a brief overview of the interim actions that have been implemented at the Site.

Surface Water Sump at the Mouth of the West Ravine

EM Science constructed a concrete collection sump (Sump-562) at the mouth of the West Ravine in 1983 to intercept and capture contaminated surface water during storm events and seepage from the West Ravine fill. The objective of the ongoing sump is to accommodate flow equivalent to a 10-year, 24-hour storm event, and to prevent the release of Site-related contaminants to a storm sewer located immediately down stream of the sump. Sump-562 and associated collection ditches have been maintained, monitored, and updated by EM Science over the years with improved controls and more efficient pumps. Non-contaminated water from Sump-562 is segregated and bypassed such that an overflow of the system only occurs during severe storm events (greater than a 10-year, 24-hour storm). The Efficacy Report demonstrated that Sump-562 has been successful at intercepting and capturing surface water at the mouth of the West Ravine. The capture capacity was shown to be as much as four times greater than the design criterion of 0.34 inches/hour. Presently, EM Science monitors rainfall precipitation on the property, and conducts a monthly inspection of the sump system. The sump is cleaned of debris approximately two to three times per year.

Storm Water Management Program

In 1987 EM Science initiated a program to collect on-property storm water from process operations areas and redirect the collected storm water to discharge points under the jurisdiction of the City of Cincinnati storm water sewer district. The intent of the program was to mitigate overflows at Sump-562 and to redirect storm water runoff to minimize infiltration into the West Ravine fill. The storm water management program was implemented in four design and construction phases between 1987 and 1988. The program has been successful in limiting the contact of storm water with contaminants in soil and fill beneath the facility. Since 1988, EM Science has continued to maintain and improve its storm water collection, such as placing concrete curbing at the edge of the mouth of the West Ravine. Currently, there is no required monitoring associated with the storm water management program.

French Drain Ground Water Collection System

A French Drain was designed and constructed between 1987 and 1988 by EM Science to intercept and collect contaminated perched ground water migrating eastward in a saturated sand unit (referred to as the Upper Sand Unit in the RI Report). The northern portion of the buried French Drain is located beneath the new aboveground tank farm, which is completely encased by concrete walls. From the new tank farm, the French Drain extends southward to the east of Building 14. Perched ground water collected by the French Drain is directed to the plant wastewater pH/Neutralization facility by Middle and South Lift Stations, and discharged to a City of Cincinnati Metropolitan Sewer District (MSD) sanitary sewer under the plant's current wastewater discharge permit. A North Lift Station located north of the new tank farm is currently not being utilized. The French Drain has demonstrated to be an effective interceptor of contaminated perched ground water flowing beneath the central portion of the facility, as presented in the Efficacy Report. Monthly monitoring includes an inspection of the system and the measurement of ground water elevations in monitoring wells upgradient and downgradient of the French Drain.

Gradient Control Well P6A

A hydraulic gradient control pumping well (P6A) was installed in July of 1992 by EM Science to prevent the eastward migration of contaminated ground water in a silty sandy clay unit (Lower Clay Unit) that extends beneath the French Drain (Figure 1-2). The well is located east of the new tank farm. When the P6A pump is operating, perched ground water is pumped to the plant wastewater pH/Neutralization facility. The gradient control pumping well has attained the goal of mitigating the potential for off-property contaminant migration to the east and southeast. With the concurrence of the Ohio EPA, P6A was shut-off after total VOC concentrations were shown to decrease from approximately 70,000 micrograms/liter (ug/L) to approximately 300 ug/L from 1992 to 1997. Ground water samples collected semi-annually from P6A have not shown an increase in total VOC concentrations since it was shutdown

Fencing

Additional fencing at the mouth of the West Ravine was constructed in January 1996 as a limited interim action during the RI. The fencing was constructed to completely restrict access to the Outfall, Sump-562, Seep-562 and exposed fill material. With this fencing, it is not possible to trespass onto the property without illegally climbing over a fence line. Access to the property is monitored by 24-hour guard service, which mans a guard station at the front-gate entrance located along Highland Avenue.

Hot Spot Delineation and Removal

Based on the results of the RI Report, EM Science conducted a hot spot delineation and removal interim action on the EM Science property in 1997. The purpose of the interim action was to further delineate, and remove by excavation if warranted, significant localized areas of high concentrations of contaminants detected at or near the surface during the RI. The activities conducted during the interim action were summarized in The Payne Firm's September 29, 1997 Technical Memorandum No. 11, Hot Spot Delineation and Removal Interim Action Report. The TM was approved by the Ohio EPA on December 5, 1997. During the interim action, four cubic yards of mercury-contaminated soil were removed and disposed of off-property at a licensed disposal facility. As documented on TM-11, a localized area of surficial PCB contaminated fill in the former East Ravine area was determined to present no unacceptable risk; and VOC-contaminated soil beneath the former Tank Farm area east of Building 4 was deferred to the FS and Remedial Action phases of work.

1.3.9 Nature and Extent of Contamination

The evaluation of the nature and extent of contamination during the RI included the: 1) division of the Site into four primary areas of VOC soil contamination, two secondary areas of soil contamination, and two ground water groups; 2) identification of the horizontal and vertical extent of contamination; 3) identification of dominant contaminants and relationships between contaminants within each area of contamination; and, 4) identified contaminant distribution patterns including likely sources and current contaminant migration pathways.

The areas of primary VOC contamination are: 1) the middle portion of the West Ravine, including the area near the former Tank Farm; 2) the mouth of the West Ravine, including the Outfall pipe and Sump-562; 3) the area south and east of Building 4; and, 4) the area south of Building 10, including the former pH/neutralization tank. The secondary areas of contamination include: the upper portion of the West Ravine, and the East Ravine. The two perched ground water groups can be characterized as follows:

- Group I includes monitoring wells with no consistent detections of non-background SSPL constituents. The wells are located in portions of the Site that are outside the areas of contamination.

- Group II includes wells with detections of non-background SSPL (Site Specific Parameter List) constituents, primarily associated with the middle portion of the West Ravine, the mouth of the West Ravine, the area south and east of Building 4, and the area south of Building 10. These two groups were used in the characterization of nature and extent and the assessment of risk.

As extensively described in Chapter 4 of the RI report, the assessment of nature and extent of contamination showed that for non-VOC SSPL constituents: 1) detections were generally consistent with levels believed to be representative of urban background in the fill with some evidence of impact to the upper portion of the Upper Till Unit, in all areas of the Site except the East Ravine; and, 2) the fill of the East Ravine contained the highest detections of most non-VOC SSPL constituents.

For the purpose of the FS, the concentration and distribution of VOCs detected during the RI are the more important SSPLs since VOCs are the primary risk and remediation drivers. The assessment of the nature and extent of VOC contamination showed: 1) the upper portion of the West Ravine was only minimally impacted by VOC contamination; 2) VOCs were present within the fill of the middle portion of the West Ravine and the underlying Upper Till and Lacustrine Units; 3) at the mouth of the West Ravine, VOCs were present in the subsurface at the point where the Outfall pipe discharged prior to the installation of

Sump-562 but only low levels of VOCs were present in the surface soil/fill; 4) VOCs were detected in perched ground water at the point where the 36-inch storm sewer discharged prior to its removal (near MW505A and MW505B) with evidence of subsurface migration to the area near MW507 and MW508; 5) VOCs were present in the Upper Till Unit and the top part of the Lacustrine Unit in the area south and east of Building 4 and had migrated through the Lacustrine Unit to the area near MW502A and MW502B; 6) VOCs were present in the courtyard of Building 10 down to the Lower Sand Zone and were migrating through the Upper Sand Unit toward the French Drain; and, 7) the East Ravine was minimally impacted by discharge of ground water contaminated with VOCs from the Upper Sand Unit prior to the installation of the French Drain.

The results of the analysis of the nature and extent of VOC contamination by area of contamination are summarized in the following paragraphs:

- The upper portion of the West Ravine is believed to primarily have been filled with soil and construction debris prior to 1956. Detections of VOCs (1,2-DCE, MEK, acetone, benzene, carbon disulfide, chlorobenzene, chloroform, methylene chloride, PCE, toluene and TCE) were largely confined to samples within five feet of the fill/native soil interface. There were also detections of VOCs in the Lacustrine Unit and the Lower Clay Unit, which may be the result of migration from the area south of Building 10. The low levels of the VOC detections and the current storm water management system are likely to severely restrict any movement of VOCs.

- The middle portion of the West Ravine is believed to have been filled with a variety of materials, including off-specification chemicals, industrial and construction debris and the debris from the 1960 fire in Building 5. The former Tank Farm was also located in this area. All SSPL constituent classes are present in the middle portion of the West Ravine. VOCs are detected throughout the fill and in the Upper Till Unit and Lacustrine Unit underlying the fill. Detected VOCs (1,1,2,2-PCA, 1,1,2-TCA, 1,2-DCA, 1,2-DCE, 1,4-dioxane, MEK, acetone, benzene, chlorobenzene, chloroform, ethylbenzene, methylene chloride, PCE, toluene, TCE, vinyl chloride and xylenes) followed a similar distribution pattern. The VOCs were detected in the area(s) of their original source (e.g. Building 4 trench drain, Building 10 process sewer or burial) with evidence of vertical migration through the fill and migration along the fill/native soil interface toward the Outfall. The maximum detections of VOCs occurred at one of the following locations depending upon the original source(s) from which the VOC was released and the mobility characteristics of the compound: near the point where the Building 10 process sewer discharged to the ravine; near the location of the former tank farm; or, near the base of the fill.

- The mouth of the West Ravine was impacted by the filling of the West Ravine, the flow from the Outfall pipe and the presence of S.R. 562. The surface fill in this area showed low levels of VOCs (< 20 μg/kg), SVOCs, D/F, cyanide, metals and PCBs. VOCs were also detected in deeper samples collected from the Lacustrine Unit south of Sump-562. The VOCs detected in the Lacustrine Unit were also detected in water samples collected from the Outfall but not in soil samples or ground water samples collected between the area around Sump-562 and the middle portion of the West Ravine, indicating that the VOC contamination in the Lacustrine Unit near Sump-562 results from infiltration of contamination discharged from the Outfall prior to the installation of Sump-562 rather than subsurface migration from the middle portion of the West Ravine. Similarly, the VOC contamination within the perched ground water monitored at MW503 was believed to result from infiltration of water from Seep-562 rather than subsurface migration. All the contaminants detected in ground water samples from MW503 were also detected in water samples from Seep-562. Prevalent VOCs were detected in the water that discharges from the Outfall and in the Lacustrine Unit at depths of 4 to 12 feet.

- The historical sources of contamination south of Building 10 included leakage from process sewer lines, aboveground tanks and the former pH/neutralization Tank. VOCs are detected to depths of fifty feet in the courtyard area in both soil and perched ground water. Concentrations of detected VOCs (1,1,1-TCA, 1,1,2,2-PCA, 1,2-DCA, 1,2-DCE, 1,4-dioxane, MEK, acetone, benzene, carbon disulfide, carbon tetrachloride, chlorobenzene, chloroform, ethylbenzene, methylene chloride, PCE, toluene, TCE and xylenes) increased with depth in the Upper Till Unit before starting to decrease to non-detectable levels. In the courtyard area, the maximum concentrations of some compounds occur in the Lacustrine Unit or the Lower Clay Unit. South of Building 11, detected VOC concentrations decreased within the Upper Till Unit and increased at the base of the Upper Till Unit and the top of the Lacustrine Unit as a result of transport of VOCs through the Upper Sand Unit before decreasing to non-detectable levels.

- The primary source of VOCs in the area south and east of Building 4 was the Building 4 trench drains which discharge to the ground from approximately 1950 to about 1967. VOC contamination in this area is largely confined to the surface fill and the Upper Till Unit. Detected VOCs follow very similar distribution pattern in this area. The actual extent of the various VOCs is dependent primarily on available mass and mobility characteristics. The maximum concentrations of detected VOCs (1,2-DCA, 1,2-DCE, MEK, acetone, benzene, carbon tetrachloride, chloroform ethylbenzene, methylene chloride, PCE, toluene, TCE and xylenes) occurred either at the northeast or southeast corner of Building 4. The maximum detected concentrations of most VOCs were within the Upper Till Unit at 10 to 20 feet below the ground surface. Generally, the concentrations decreased quickly with the Upper Till Unit and dropped to non-detectable levels within the top portion of the Lacustrine Unit. At the northeast corner of Building 4, VOCs increased within the Lacustrine Unit, possibly as a result of transport of contaminants through the Upper Sand Unit, before rapidly decreasing within 10 feet to non-detectable levels. Below the Lacustrine Unit, there are low level (<25 μg/kg) detections of acetone and toluene. VOCs were detected to the south at VE509 and MW502A.

- The contamination in the East Ravine results from the burial of industrial and construction debris within the ravine and the contamination are primarily confined to the fill itself. Low levels of VOCs were detected, primarily along the western edge of the ravine where VOCs that migrated through the Upper Sand Unit prior to the placement of the French Drain discharged to the ravine. The results of this migration were detected from the area near from P6 south to MW15. SVOCs, metals, cyanide, PCBs and D/F were detected within the fill with no distinct concentration gradients as were observed in the other source areas. The relatively immobile nature of these compounds has restricted migration preventing both contamination of native soil and formation of concentration isopleths within the fill. The contamination is to a large decree where it was originally placed within the fill. VOCs

(1,1,2,2-PCA, 1,1-DCA, 1,2-DCA, 1,2-DCE, 1,4-dioxane, MEK, acetone, benzene, carbon disulfide, ethylbenzene, isobutyl alcohol, methylene chloride, PCE, toluene, TCE and xylenes) were detected in both fill and native soil.

1.3.10 Contaminant Fate and Transport

The overall objective of the contaminant fate and transport analysis during the RI was to evaluate the potential for Site contamination to reach points where it can pose a risk to human health or the environment. The fate analysis focused on the mobility and longevity of certain soil and ground water contaminants detected beneath the Site and their degradation products.

The implementation of the French Drain, P6A, Sump-562, and the storm water management program by EM Science before the RI was initiated has significantly minimized the off-property migration of SSPL contaminants. The data needs for the assessment of contaminant migration within the Perched Ground Water System, therefore, were developed from the results of the RI field investigation, and the objectives of the baseline risk assessment. The SGM and the results of the nature and extent of contamination investigation demonstrated the silt and clay rich Perched Ground Water System has limited horizontal and vertical potential migration pathways, and that the Confining System is an effective barrier between the Perched Ground Water System and the Norwood Trough Aquifer. The specific pathways addressed in the analysis of perched ground water migration were: 1) contaminants migrating from the area south of Building 10 to the eastern property boundary, which yielded conservative upper bound estimates of the potential concentrations at the eastern property boundary; 2) contaminants migrating in perched ground water at off-property locations in the southern portion of the Site; and, 3) contaminants migrating vertically from primary areas of VOC contamination.

The results of the analysis of migration of contaminants from the area south of Building 10 to the eastern property boundary were used in the evaluation of the potential risk to a future off-property residential user of ground water. The evaluation of potential for vertical transport from the areas of contamination yielded breakthrough times within certain geological units in the SGM.

The results of the contaminant transport analysis in perched ground water are conservative approximations since assumptions incorporated into each step of the transport model development were made so as to not underestimate the potential concentrations present at, or the time periods required to reach, the receptor locations. Conservative assumptions were made with respect to the model parameters, the variability of current Site physical characteristics, and the future stresses applied to the modeled systems. The results of the contaminant transport analysis indicated that only a limited number of the more mobile indicator contaminants evaluated are present in sufficient quantity (i.e., total mass) and have mobility characteristics such that the potential exists for measurable quantities of these contaminants to be transported to the eastern property boundary. The transport analysis indicated that the physicochemical characteristics of less mobile contaminants (such as PCBs, dioxins and furans and many SVOCs) result in transport times through the Vadose Zone to the Upper Sand Unit that are sufficiently great (500 years or more) that migration of these contaminants to receptor locations was not considered to be a risk concern. The results of the transport evaluation from the area south of Building 10 to the eastern property boundary were used within the baseline risk assessment. The evaluation of the potential for vertical contaminant migration indicated that breakthrough times for transport of contaminants vertically from the areas of contamination were greater than 10,000 years assuming that the mechanisms required for transport are present. Review of the geological and hydrogeological data supports the conclusion that mechanisms for vertical migration are limited to diffusion and minimal infiltration. In addition, there is a very low to negligible potential that the Norwood Trough Aquifer would ever be impacted by contaminants detected below the Site due to the limited mechanisms for vertical migration and a limited amount of total contaminant mass.

1.3.11 Natural Attenuation Evaluation

Although U.S. EPA recognizes that "the natural attenuation processes that are at work in such a remediation approach [as monitored natural attenuation] include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and ground water," U.S. EPA expects that monitored natural attenuation "will be used in conjunction with active remediation measures (e.g., source control), or as a follow-up to active remediation measures that have already been implemented."

After the RI, a preliminary assessment of monitored natural attenuation was conducted to determine if conditions favorable to reduction of the concentrations of VOCs are present in media beneath the site. The methods and results of this assessment, which are summarized below, were presented to the Ohio EPA in the Payne Firm's July 2, 1999, <u>Natural Attenuation Technical Memorandum No.17</u>. Ohio EPA comments dated August 5, 1999 were received and a revision to TM-17 was submitted in January 2000. The assessment included evaluation of historical site data (including pre-RI, RI, and post-RI analytical data and potential effects from interim actions), analysis of ground water samples from four areas of the site for natural attenuation indicator parameters, and microcosm studies to assess the biodegradation potential of the naturally-occurring site bacteria.

As presented in TM-17, four discrete areas of the Site were examined based on areal extent of VOCs and hydrogeologic differences:

- Monitored Natural Attenuation Area One (MNA Area 1) – Upper Sand Unit D1 (Perched Zone I), from the central portion of the site to the French Drain;

- Monitored Natural Attenuation Area Two (MNA Area 2) – Sand seams in the upper portion of Lacustrine Unit D2 (Perched Zone II), at the mouth of the West Ravine;

- Monitored Natural Attenuation Area Three (MNA Area 3) – Sand seams in the lower portion of Lacustrine Unit D2 (Perched Zone II), downgradient of the mouth of the West Ravine; and,

- Monitored Natural Attenuation Area Four (MNA Area 4) – Lower Clay Unit D3 (Perched Zone II) beneath the filled East Ravine.

Individual VOCs found at the Site were evaluated within five associated chemical groupings (four comprised of chlorinated compounds, one of non-chlorinated aromatics) for purposes of qualitatively assessing the potential significance of biological or chemical processes of natural attenuation in reducing the mass, toxicity, mobility, volume, or concentration of the VOCs in soil and ground water at the Site. This assessment was completed in part by evaluating the ratio of chlorine-heavy to chlorine-light compounds within a group over time. Within each of the four groups of chlorinated VOCs, chlorine-heavy compounds (three or four chlorine atoms per molecule) normally degrade to chlorine-light compounds (one or two chlorine atoms), although the potential direct release of chlorine-light compounds at the Site requires caution in interpretation of changes in chlorine-heavy to chlorine-light ratios over time. The five VOC groups consist of:

- Chloroethenes (CEs) contain two carbon atoms joined by a double bond, one to four chlorine atoms, and a sufficient number of hydrogen atoms to stabilize the molecule. The compounds are tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-DCE), and vinyl chloride (VC). Within the group, more-chlorinated compounds (PCE and TCE) degrade to less-chlorinated forms (1,1-DCE, 1,2-DCE and VC). Chlorine-heavy CEs tend to degrade more readily under reducing conditions.

- Group I Chloroethanes (CA-1s) contain two carbon atoms joined by a single bond, one to three chlorine atoms, and a sufficient number of hydrogen atoms to stabilize the molecule. Within the group, more chlorinated compounds degrade to less chlorinated forms. One example of a breakdown path is 1,1,1-trichloroethane (1,1,1-TCA) to 1,1-dichloroethane (1,1-DCA), which may eventually decompose to chloroethane and/or directly to innocuous compounds.

- Group II Chloroethanes (CA-2s) contain two carbon atoms joined by a single bond, two to four chlorine atoms, and a sufficient number of hydrogen atoms to stabilize the molecule. Within the group, 1,1,2,2-tetrachloroethane (1,1,2,2-PCA) degrades to 1,1,2-trichloroethane (1,1,2-TCA) and then to 1,2-dichloroethane (1,2-DCA). The latter compound is relatively persistent but can degrade to innocuous byproducts over time.

- Chloromethanes (CMs) contain a single carbon atom, one to four chlorine atoms, and a sufficient number of hydrogen atoms to complete the molecule (i.e., carbon tetrachloride [PCM], chloroform [TCM], methylene chloride [DCM], and methyl chloride [CM]). These compounds are fairly stable. Generally, decomposition rates of PCM slow at TCM or DCM.

- BTEX compounds are benzene, toluene, ethylbenzene, and xylenes. Their basic structure is the benzene ring, composed of six carbon and six hydrogen atoms. In the three other compounds, one or more side chains replace one or more of the hydrogen atoms. Aerobic degradation is generally more rapid than anaerobic for the same compound in this group.

As discussed in Section 1.6, interim actions have been performed at the Site to control the primary migration pathways. These actions have had various effects on the concentrations of detected VOCs at different times and were evaluated as part of the assessment. The interim actions have included:

- A ground water collection sump was installed in 1983 and continues to operate at the mouth of the West Ravine. The collection sump intercepts Vadose Zone Fill and sand seams in Lacustrine Unit D2. The magnitude of detected contamination at the sump appears to have decreased slightly since operations began.

- A French Drain was installed in 1987-1988 to intercept ground water from the Upper Sand Unit D1 and continues to operate. This system is located at the eastern part of the site between the central manufacturing area and the East Ravine. There has also been a wastewater closeout at the Site to control storm water discharges. This system has reduced recharge to the Upper Sand Unit. Initial discharges from the French Drain were much greater than the current discharge, suggesting dewatering of a portion of the perched aquifer. Dewatering of part of the Upper Sand Unit was evidenced by subsequent drying or reduced yield of several wells screened in the unit. A concurrent decrease in contaminant concentrations by one to two orders of magnitude, and in the variety of detected contaminants appears to have also occurred.

- A pump was installed in Piezometer P6A in 1992. The pump extracted residual contaminated ground water from the Lower Clay Unit D3. This unit is believed to have been contaminated from Upper Sand Unit D1 prior to installation of the French Drain. P6A was shut off in 1997 following demonstration of its effectiveness and the reduced off-property contaminant migration potential.

In addition, trend analyses of historical ground water data were performed to provide more quantitative evaluations of VOC concentration changes over time. For this evaluation, individual VOCs found at the Site were reviewed in groupings of Total Chlorinateds (Ces, CA-1s, CA-2s), total Chloromethanes (CMs) and Total BTEX.

The preliminary assessment of monitored natural attenuation identified variable results for purposes of qualitatively assessing the potential significance of biological or chemical processes of natural attenuation in reducing the mass, toxicity, mobility, volume, or concentration of the VOCs in soil and ground water at the Site. The observed effects from the review of existing data for the Site indicate the following:

- The evaluation of historical Site data (including analytical data and potential effects from interim actions) identified:
  - Order of magnitude reductions in the magnitude of contamination at MNA Area 1 following installation of the French Drain;
  - Elimination of CA-1s at MNA Area 2 following installation of the French Drain;
  - Order of magnitude reductions in the magnitude of contamination at MNA Area 3 following installation of the Collection Sump;
  - Order of magnitude reductions in the magnitude of contamination at MNA Area 4 following installation of the French Drain and Pumping at P6A;
  - Change in proportion of CEs from chlorine-heavy to chlorine-light compounds at each area; and,
  - Change in proportion of CA-1s and CA-2s from chlorine-heavy to chlorine-light compounds at MNA Area 1.
- The analysis of ground water samples from four areas of the site for natural attenuation indicator parameters verified favorable dissolved oxygen, methane, oxidation-reduction potential, chloride, and ferrous iron levels at MNA Areas 1, 2, and 3.
- Microcosm studies to assess the biodegradation potential of the naturally-occurring site bacteria suggest bacteria in soil at MNA Area 1 could have an effect on CEs.

In summary, the assessment demonstrates that there are conditions beneath the Site that suggest that biological and chemical processes of monitored natural attenuation are occurring, or have the potential to occur to reduce the mass, toxicity, mobility, volume, or concentration of some VOCs (particularly CEs and CA-1s) in soil and ground water.

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Number of pages including cover page: 6

Message: Don - Here's the pages re: the supplemental risk evaluation to ODOT workers.

Joe